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ABSTRACT

Computer based information search services, ISS's, of the type that provide on-line literature searches are analyzed from a system's viewpoint using a continuous simulation model. The analysis shows that the observed growth and stagnation of a typical ISS can be explained as a natural consequence of market responses to the service together with a business orientation on part of the funder. The study also gives an analysis of managerial decision making for an ISS. (Author)

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GROWTH DYNAMICS OF INFORMATION SEARCH SERVICES

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ABSTRACT

Computer based information search services, ISS's, of the type that provide on-line literature searches are analyzed from a system's viewpoint using a continous simulation model.

The analysis gives that the observed growth and stagnation of a typical ISS can be explained as a natural consequence of market responses to the service together with a business orientation on part of the funder.

The study also gives an analysis of managerial decision making for an ISS.

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1. INTRODUCTION AND BACKGROUND

The growth in the volume of scientific and technical information has followed an exponential path since the middle of the eighteenth century and has now reached a level of about 100, 000 published journals. The need for efficient procedures for searching and accessing the body of recorded knowledge has increased accordingly and resulted in a number of changes in these procedures.

The traditional depositories for literature are libraries and the traditional access tools are the library catalogs. In order to provide adequate service to its patrons the libraries have responded to the growth of information and structural changes in the scientific literature[1] by adapting the cataloging procedures[2] and by instituting cooperative systems between themselves. However, the slower growth of library collections compared to that of the volume of information[3] together with an increasing reliance for dissemination of results on the journal article,which is not searchable in traditional library catalogs, made the libraries unable to satisfy many information needs of the scientific community.

Around 1840 secondary journals, or abstract journals, began to appear[4] to provide better access to the journal literature. These publications soon began to grow in number at the same rate as the primary journals and by the 1960's there was again a need for more efficient access tools. A number of computer based approaches were tried[5], initially based of magnetic tape versions of the secondary journals with organizational couplings to the producers but later developed into independent information search services, ISS's, usually hosted and sponsored by a library.

II. PROBLEM STATEMENT

The problem we are addressing in this study is that of irregular growth of ISS's: after a period of initial growth the number of users of an ISS typically levels off dramatically (see Figure 2) even though the potential market is not nearly penetrated. The decline in growth sometimes makes it difficult for the managers of the ISS's to justify the continuation of the service. Since the setting up of an ISS requires quite a large initial investment the stagnation could also activate economic concerns.

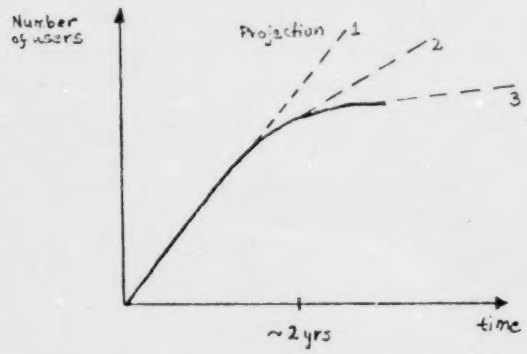

Figure 2.
Typical development of the number of users of an ISS.

The difficulty in maintaining growth until the target market is penetrated, or until an economically self-sustaining level of operation is reached, can be a strong inhibiting force on the growth of the number of surviving ISS's. Since overoptimistic forecasts for growth are common, over-expectations on part of the funder occur, and the problem is often referred to as that of "insufficient growth." If the current mental pictures and beliefs prevail and are used as a basis for forecasts and expectations the fate of the on-line based ISS's can be the same as that for the SDI operations of the mid-1960's: after a period of success with growth in both the number of services and the number of users per center the latter stagnated at a level that was too low to justify continued support. The number of SDI operations declined rapidly, and today the SDI function is carried out by a few big centers, or offered as an option by the larger ISS's.

Whenever overexpectations occur and reoccur there is usually a lack of knowledge of underlying forces. The established knowledge of user behavior and market reactions is insufficient for guiding the ISS managers, which is illustrated by the following quote:

> "... totally inadequate conceptions concerning STI [Scientific and Technical Information] users are guiding the thinking of many STI/SS [Scientific and Technical Information Systems and Services] designers and managers. Unless and until research is done that reshapes current 'mental pictures' of who can or might use STI/SS's, hopes for seeing major improvements in the delivery and utilization of such systems and services are bound to be frustrated."[6]

The purpose of this paper is to present an analysis of causes for the growth behavior of ISS's. It offers an explanation for the observed growth development and can serve as a basis for further understanding needed for effective management decision making. The analysis is based on results from computer simulations with a model of a typical ISS.

III. BOUNDARY FOR THE STUDY AND THE STRUCTURE OF AN ISS

To understand the behavior of any system it is necessary to include in the study all the factors that contribute to the behavior. This means that the boundary for a problem oriented systems study typically is different from what is traditionally held to be the system boundary. For a study of the growth of an ISS the appropriate boundary must iclude, in addition to the ISS itself, both the funder and the users since their decisions and actions have a direct effect on the ISS[7].

To illustrate the structure of an information search service we can relate its functions, in terms of "machines", to the overall activity of user access to the scientific literature (Figure 3):

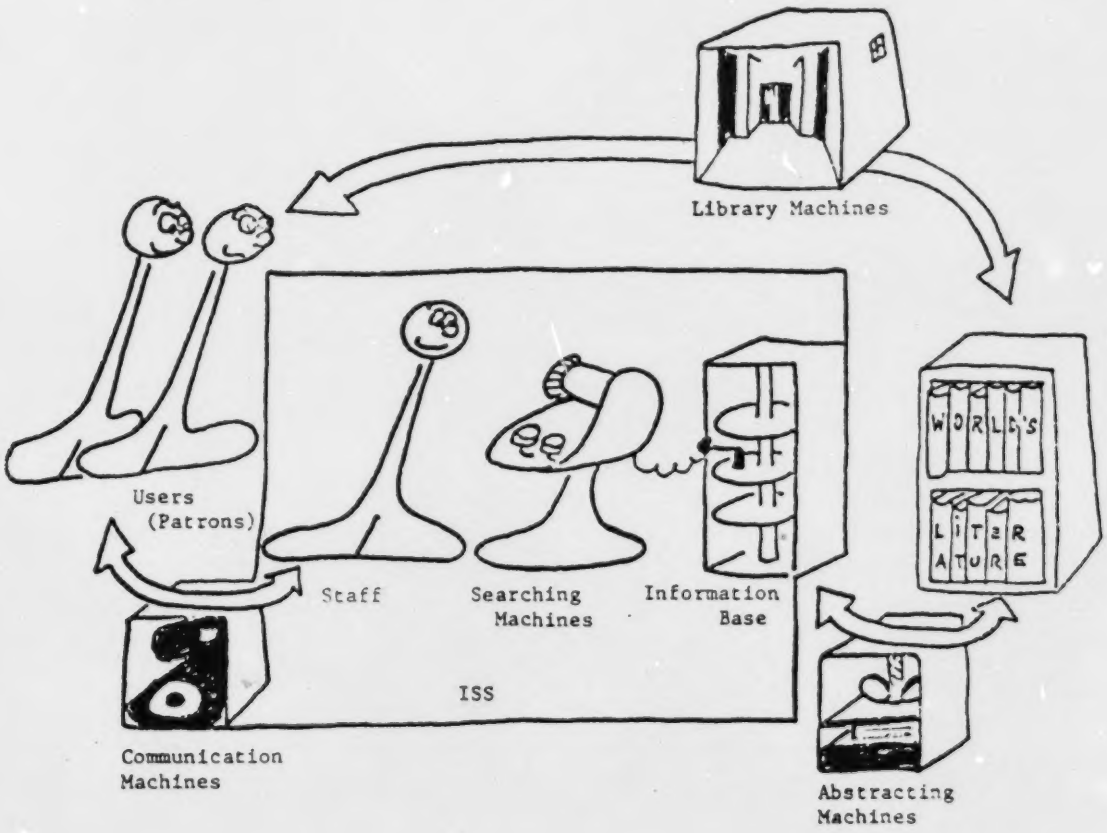

Figure 3.
The structure of an ISS.

The function of the library machines is to locate a specific document and make it available to the user. The function of the abstracting machines is to create a machine-readable description of documents, including a description of the content. For the purposes of this study we assume that the operation of these two types of machines is done by organizations other than information search services.

The function of an ISS.

The function of an ISS is to respond to a query, or search request, from a user by performing a computerized search in the information base to locate literature references of relevance to that request.

The language used by the abstracting machines is different from that of the typical user and the first task for the ISS staff is to translate the user's search request into the appropriate query language. This process can be described as finding the appropriate key-words or search terms. In an on-line environment this process is usually done in stages, so that intermediate search results are, at least partially, displayed and evaluated and on basis of this evaluation the search statement is modified. It is, however, important to have the user be specific about his search request, and typically he is asked to submit his request in writing. These written search requests are analogous to orders in a manufacturing firm, and they are subject to two primary scheduling delays: the subject specialty of the request is matched with the subject competency of the ISS staff and with the coverage of the available data base. The latter matching introduces a delay since, because of storage limitations on part of the information supplier, it is common to make only part of the total information base available at any one time. System down-time adds to this delay.

In all on-line information search services the delays due to scheduling and distribution exceed the actual search time at the computer terminal by several orders of magnitude.

The actual role of the ISS staff varies: in some cases the staff carries out the searches, either with the user present or alone, and in others the user does the actual searching with the staff member coaching. In either case the output of the ISS is dependent on the staff resources available.

The performance of an ISS is evaluated from different viewpoints: management evaluates the goal fulfillment, the funder, the users, and the potential users evaluate the service in some utility terms. All these evaluations lead to decisions and actions that affect the future operations of the ISS.

The management decisions.

Management tries to keep the delivery delay for the service, or the response time as it is sometimes called, at an acceptable level by allocating staff effort to the "production" function, i. e. perform the information searches. The resources that are not needed to achieve the delivery delay goal are used for user assistance and marketing. There is a constraint for the allocation policy since a certain minimum effort is required for user assistance. Part of this minimum is spent on administrative work.

A less obvious way for management to increase the productive capacity is to decrease the staff time spent on each query. Such changes can only be done slowly since they involve a learning process on part of the staff and an adjustment time for the users. The time spent per query has a strong effect on the quality of the service and is therefore a high level policy variable. In the present study we assume that the quality goal is not changed.

The users and their decisions.

The definition of a "user" of an ISS is not unproblematic when there is no formal contract, like a subscription, on which to base the definition[8]. In this study a user is defined as a person who decides to use the ISS, and he remains a user for a "normal user time", unless the effect of delivery delays will make him terminate his interactions sooner.

The users submit queries according to their normal propensity to query. This propensity, however, is influenced by the experienced delivery delay: if this is long then the propensity to query is lower than normal.

The potential users.

The potential users decide to become users on the basis of their perception of the value of the service, measured by perceived delivery delay, and the intensity of the marketing effort[9]. The entry rate is also subject to influence from the proportion of actual users to potential users: the

word-of-mouth effect, which has a positive influence on awareness and entry rate, grows at first with the number of users but saturates when the proportion of users is high. There is also a general saturation effect which makes it more difficult to attract and recruit users as the market penetration approaches 100 per cent.

The funder and his decision.

The funder's assessment of the ISS operations consists of both a critical and a supportive aspect. On one hand the ISS must prove its worth in the marketplace and the criteria used for the critical evaluation are usually economic or some measure of market penetration, i. e. how successful the service is in terms of growth in queries or users[10]. The critical component will lead to a reduction of support if the growth is not sufficient compared to the funder's norm.

The supportive component rests on the realization that low performance in terms of growth can be the result of too little resources. If the funder is committed even low user satisfaction might lead to an increase in the funder's willingness to support the ISS. To this latter effect there is, however, a time limit so that if user satisfaction does not go up in a reasonable period of time the funder is forced to the conclusion that the ISS does not provide an adequate service to the users.

IV. SYSTEM DESCRIPTION

Behavior is the aggregate of system activity, which includes decision making and actions. Actions lead to changes in the system. When something is done the outcome also changes future doings either because of physical changes in the system or because of psychological changes, i. e. learning. Actions are prompted by decisions. Decisions are influenced by the state of the system which, in turn, is affected by actions. In systems with human decision makers it is always important to account for the possibility that the perceived state of the system can be different than the actual, and to realize that it is the former that is influencing the decision making. Thus system activity can be described in terms of feedback loops which are closed paths representing effects of a decision on the system and on future decisions via information feedback.

A decision is influenced by very many information feedbacks but it is not desirable to include them all in a system description since an increase in detail means a loss of perceivability and hence understanding. This means that the variables used to describe the system must be selected with care. It is easy to construe a thousand reasons for a decision, but the "good reasons" are few; the set of variables chosen to describe the state of the system must be able to represent all the "good reasons" for the decisions in the system.

To study an information search service it is necessary to include the number of users and the number of queries as variables describing the state of the system, and to study the growth of an ISS it is also necessary to include the productive resource staff.

In the following the feedback loops affecting these variables will be described. The system loops are numbered in one sequence and prefixed by the initial of the variable upon which they have the primary influence.

Loops affecting the number of users.

The feedback loops affecting the number of users are given in Figure 4.

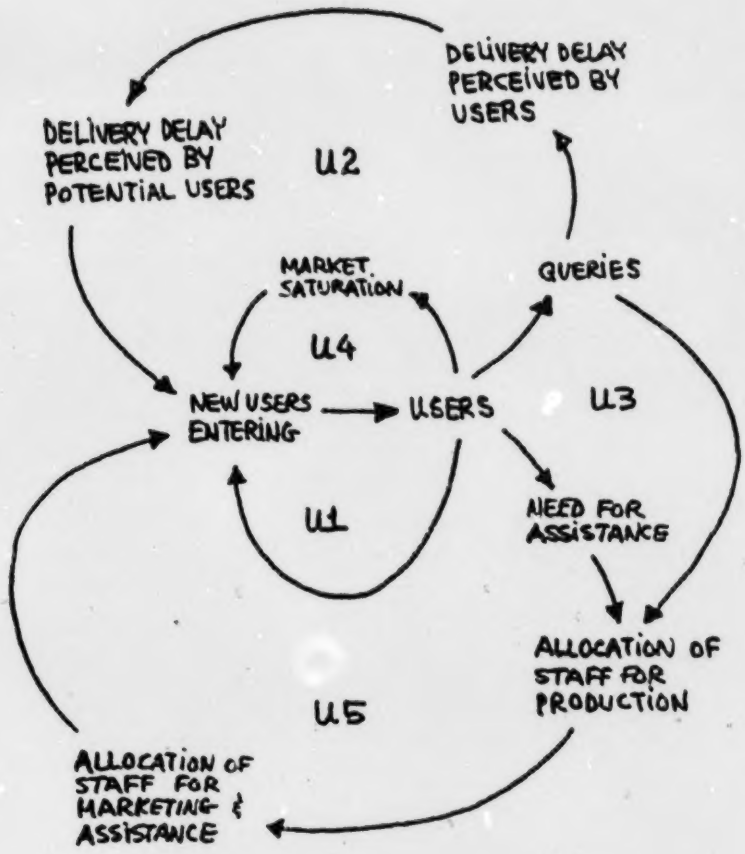

Figure 4.
Feedback loops affecting the number of users.

Loop U1 represents the natural tendency for growth in the number of users. There is an intrinsic need for an ISS[11] and the most important factor affecting the growth is awareness of the service which is, in turn, largely determined by word-of-mouth although the marketing effort by the ISS night prompt the actual decision to become a user[12]. Thus until the ISS has reached its service capacity the number of users could grow at an increasing rate.

Loops U4 and U2 are negative loops that controls the growth of users. Loop U4 is the market saturation effect which represents the increasing difficulty in recruiting new users when more and more of the potential users have actually become users. The negative effect contained in loop U2 is the effect from delivery delay on entries. As more users enter

the number of queries will increase which will lengthen the delivery delay which will reduce the number of entries.

Loop U3 shows another force inhibiting the number of entries: as the number of queries increase more staff is needed for production, i.e. searching which will make less staff resources available for marketing and user assistance. This negative effect is counteracted by the effect of loop U5 which is to make it more difficult to allocate staff for production as the need for assistance increases.

Feedback loops affecting the number of queries.

In Figure 5 the feedback loops affecting the number of queries are shown together with the previously discussed loops. Loop Q6 represents the effect that users when perceiving a good service, i.e. short delivery delay, show an increase in their propensity to query. Similarly there is a decrease in the propensity to query when delivery delay is long. A build up of query backlog lengthens the delivery delay and this has a negative effect on the number of incoming queries. This effect is amplified by loop U2 which gives a reduction in the number of users, and hence queries, when delivery delay is long.

The managerial policy for resource allocation is represented in loop Q7: when the query backlog rises the allocation of staff to production is increased which will increase the answer rate and reduce the backlog. The delivery delay is shortened by both the increase in answer rate and the reduction in query backlog. Loop Q8 shows a dysfunctional effect, in terms of control of the query backlog, of the resource allocation decision. As the answer rate goes up the delivery delay gets shorter which eventually will stimulate the users to submit more queries and potential users to become users.

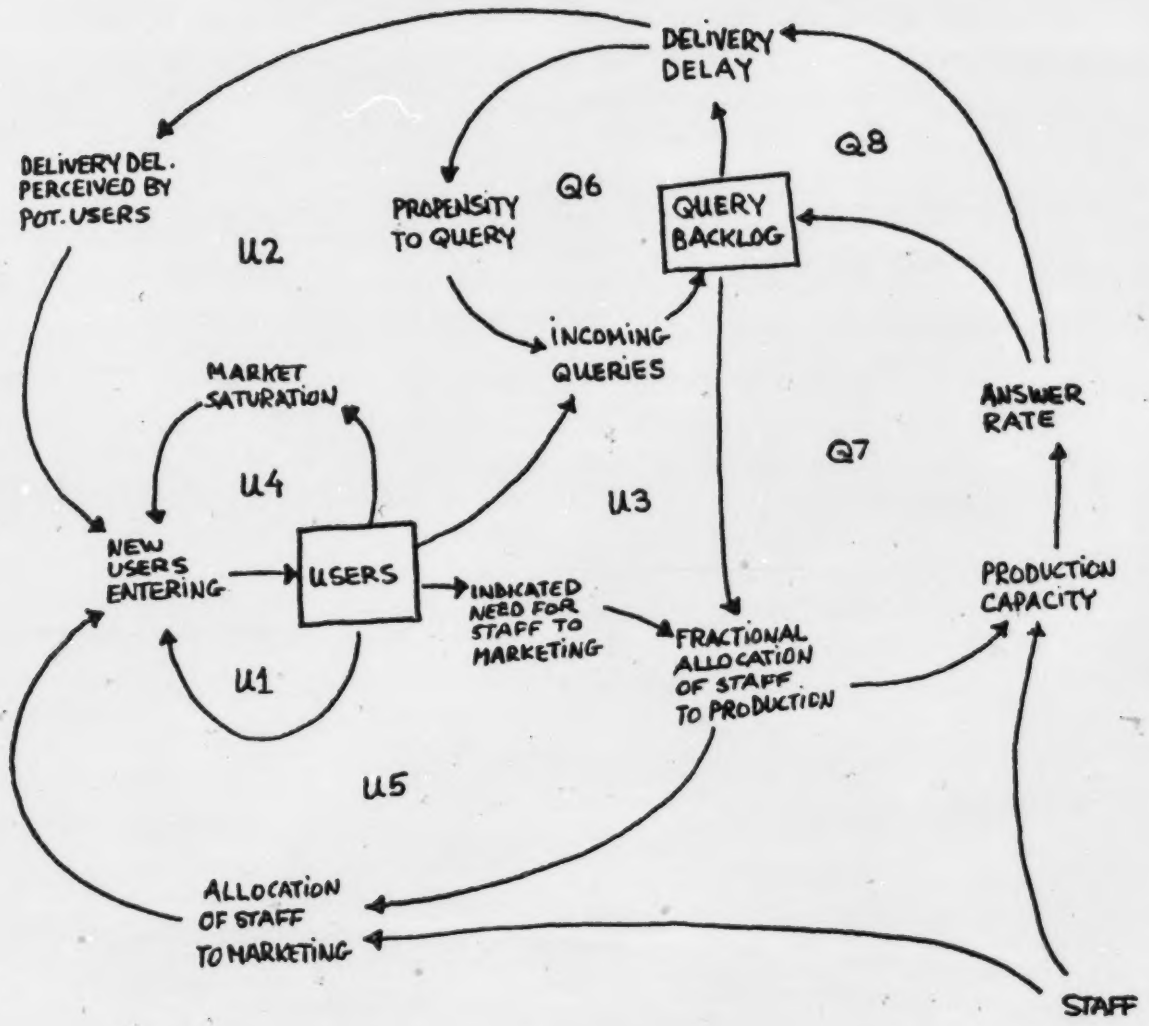

Figure 5
Feedback loops affecting the number of users and queries

Feedback loops affecting the number of staff.

Figure 5 gives all the loops necessary to analyze the behavior of an ISS if staff was held constant. For some studies this would be adequate since an ISS sometimes is set up as a research project or experimental activity with a fixed budget. The most common setting for an ISS is, however, is to be part of a larger organization, such as a library, and subject to budgetary concerns. It is therefore necessary to include the feedback loops affecting the number of staff. These are shown in Figure 6.

Loop S9 represents the compensation for leaving staff. As staff increases so will the number of staff leaving, assuming that the average time to stay is not changed. This will lead to an increase in the number of desired hires and eventually hires.

The expansion of the ISS in terms of staff is shown in loop S10. In the organizational setting that is typical for an ISS, justification for expansion is normally based on a demonstrated "need" such as a high backlog of queries or long delivery delay.

There are two primary constraints on the expansion. Loop S11 represents the funder's willingness to support the ISS. If delivery delays are long for a sustained period of time his willingness to support will decline since solicited evaluations of the service will be low.

The other constraint is economical and is represented by loops S12 and S13. The setting up of an ISS requires a relatively large investment and its operation has high and visible marginal costs, such as search fees to the information wholesalers and telecommunication costs. It is therefore common to require the ISS to recover some of these costs[13]. Since there are usually no expectations to recover the initial investment the economic constraint contains only variable costs: staff salaries and search costs. The funder then expects a certain volume of searches per staff, and the queries per staff ratio is determining the economic constraint.

Loop S12 is a positive loop where an increase in staff gives shorter delivery delay, more incoming queries, and an improved queries per staff ratio, which will reduce the economic constraint on hires.

Loop S13 is a negative loop since an increase in staff will lead to a worse queries per staff ratio and a negative influence on hires.

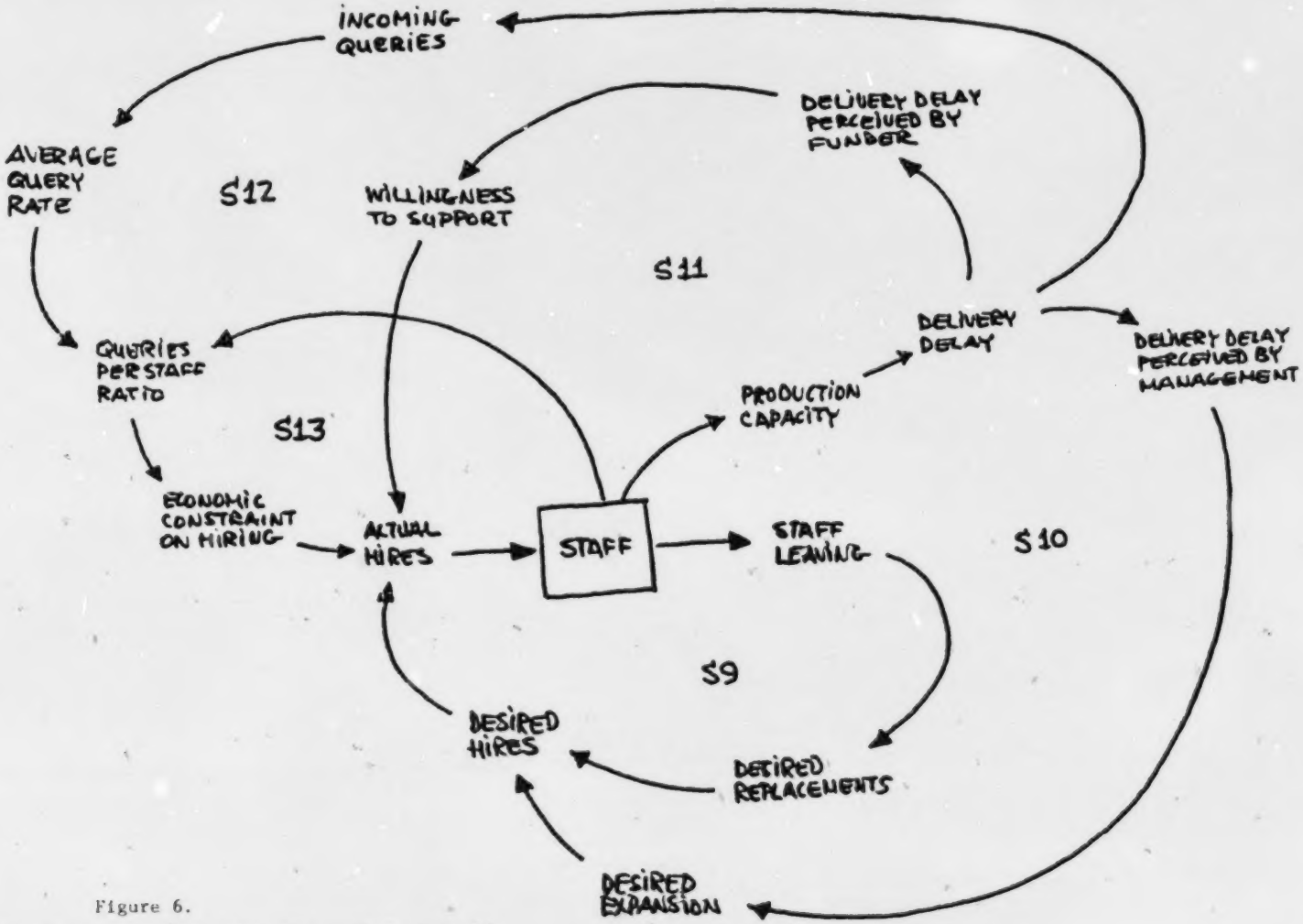

Figure 6.
Feedback loops affecting the number of staff.

V. THE SIMULATION MODEL AND BEHAVIOR OF AN ISS

The numerical values chosen for the parameters of the simulation model are representative of an ISS in an academic setting. The quantified model represents a synthesis of information from literature sources, correspondence with, and study visits to operational ISS's.

The typical ISS thus simulated has initially a staff of three persons. The average number of searches per staff is ten per week, and management tries too keep the delivery delay at half a week. The potential market for the ISS is 2000 users who have a normal information need of close to two searches per year.

Figures 7-a and 7-b show the behavior of the system variables resulting from a simulation run of the first 240 weeks of operation.

The simulated ISS grows rapidly in terms of number of users for the first 60 weeks, and then the typical decline in growth occurs when the number of users is about 800. From then on the growth is significantly slower but the ISS is satisfying the funder's economic requirements and is not doing too badly in keeping the delivery delay at the norm so the service expands and has a staff of 4.4 at the end of the 240 weeks. The number of users at that time is 1137, which means a market penetration of 57 percent. The ISS receives 35 search requests, i.e. queries, per week, and the number of new users is 25 per week, which means that the percentage "return users" is 29.

The behavior of the simulation model is realistic in both qualitative and quantitative terms and by analyzing the underlying forces we can obtain an explanation for the behavior.

The following analysis will show that the decline in growth is a direct consequence of market responses to the ISS operations.

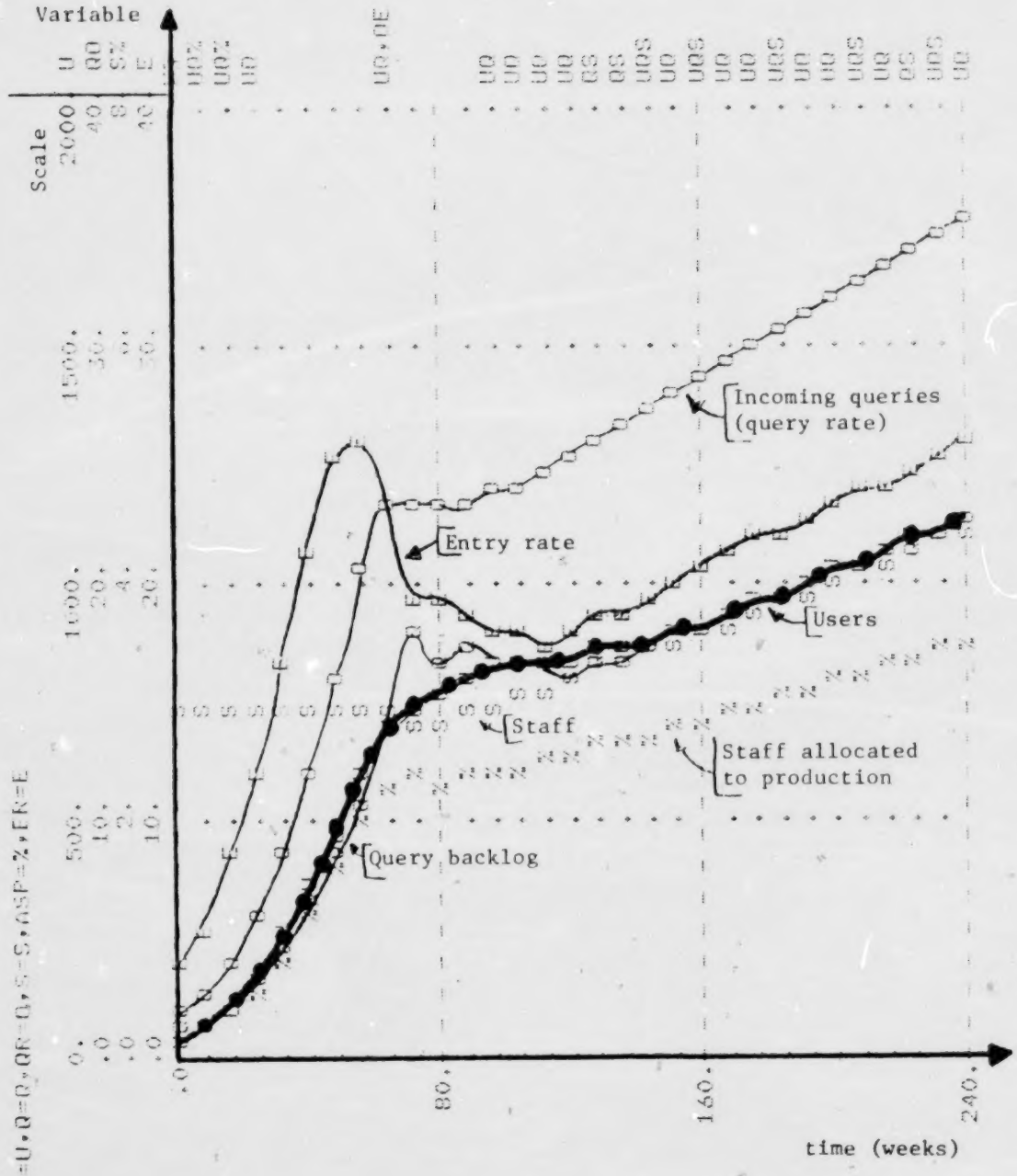

Figure 7-a.

Reference run for the simulation model.

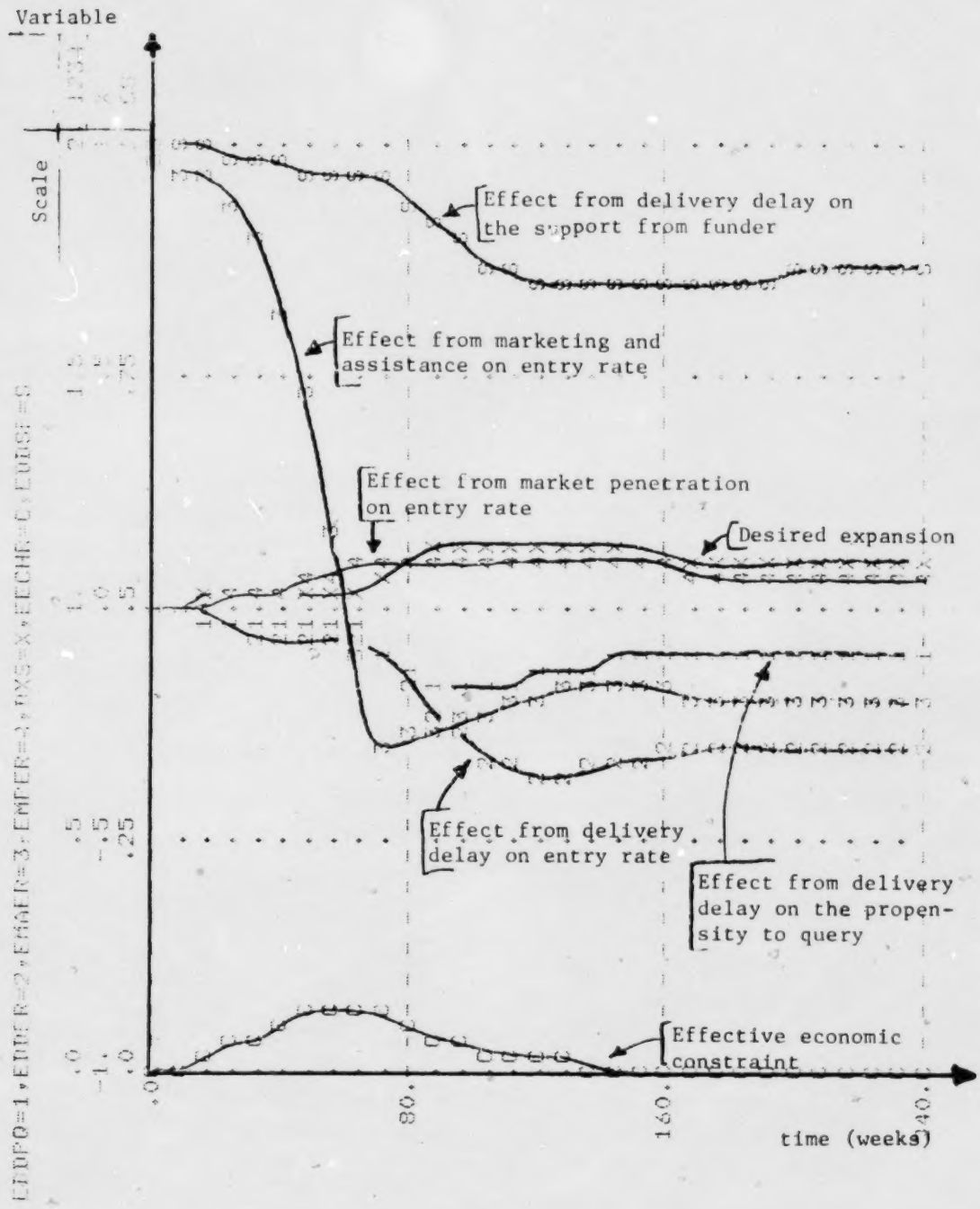
Variable
Scale
Effect from delivery delay on the support from funder
Effect from marketing and assistance on entry rate
Effect from market penetration on entry rate
Desired expansion
Effect from delivery delay on entry rate
Effect from delivery delay on the propensity to query
Effective economic constraint
80.
160.
240.
time (weeks)

Figure 7-b.

The "natural" growth of the ISS (loop U1) is amplified during the first year when there is not enough workload, in terms of queries, to conflict with the marketing activities. Users are attracted to the service by relatively intensive marketing and adequate assistance, and by a delivery delay that is practically at par with their requirements. As more and more resources are needed for production there is a declining effect from marketing and assistance on the entry rate (loop U3).

The reactive character of the allocation policy means that the ISS management will only allocate resources to production when there is an established need to do so on the basis of a build-up of queries in process (loop Q7). The fast growth in terms of users will lead to increasing difficulties in keeping the delivery delay at the norm. The adverse effects on the existing users' propensity to query are counteracted by an increase in the allocation of staff to production and for the first 60 weeks the propensity to query does not go much below normal but goes down after that and has a negative effect on the query rate (loop Q6). The effect from the increase in delivery delay on entry rate (loop U2) takes longer to reach its full strength; the potential users do not have a first hand experience of the service and there is a delay before the users' perceptions are known. Once the potential users have made an assessment of the service it is difficult for the ISS to change it; the people who have decided that the service is not good enough to try will naturally be less inclined to pay attention to information from the ISS. Changing the potential users perception is therefore a slow process.

For the first 60 weeks the awareness of the service is growing and the word-of-mouth effect, or the effect from market penetration, contributes increasingly to the rate of growth in users (loop U4). The typical ISS does not grow enough to experience market saturation effects.

The effect from marketing and assistance on entry rate is decreasing for the first 70 weeks which causes a decrease in the entry rate after about one year in spite of the relative good delivery delay situation and high awareness of the service. After week 70 the effect from marketing and assistance increases somewhat; this is partly due to the recognition of the need for assistance for the growing number of users (loop U5) but it is also helped by the increasing negative effect from delivery delay on entry rate which reduces the growth in users (loop U2) so that the relative effect of the allocation of staff to marketing and assistance is increasing.

The causes for the overshoot in entry rate and thus for the dramatic decline in the growth of the number of users is that the staff capacity available for marketing and assistance is declining as a consequence of the necessary allocation of staff for production (searching). The flow of incoming queries is,however, still to strong to make it possible for the ISS to keep delivery delays at the norm; a condition which will have an incremental effect on the decrease in entry rate (loop U2).

The initial growth of the ISS is primarily driven by the relatively high marketing effort during the first year. Low awareness of the ISS is one cited cause of failure to grow,[14] and other studies support the necessity of marketing activities for achieving growth.[15] At the same time, however, it is important to keep the delivery delay at an acceptable level since it is the principal determinant of service quality. So the problem facing the ISS management is to balance the commitments to the users; accepting a user means, on one hand, a commitment to spend resources on assistance but it also implies a longer term commitment to answer submitted queries. This latter commitment is not always recognized as being long-term but observed behavior of ISS's indicates that the demand for resources for production per user will increase after a few years.

The difficulty in finding an ideal balance where it is possible to give adequate assistance to every user and still keep the delivery delay goal is illustrated by the presented model and simulations; there are delays of various magnitude for the effects of the ISS operations to result in decisions by users and potential users. Too high expectations are generated and management will have difficulties in responding adequately to both the demand for assistance and production, i.e. searching.

The predicament of the ISS management is enhanced by the funder's reactions. The different phasing of the users' needs for production and assistance makes it difficult to avoid dissapointment in one respect or the other. If too much emphasis is put on satisfying the need for assistance then the delivery delay will be longer and discourage users from entering (loop U2) and eventually reduce the funder's willingness to support the service (loop S11) which will hinder expansion and slow down growth. If the production aspect is neglected enough the economic constraint will also be in effect (loops S12 and S13).

If too little emphasis is placed on marketing and assistance some users will be discouraged from using the service, and since delivery delays

will be relatively short there is no visible justification for expanding the service (loop S10). This catch-22 like situation is sometimes a reality: to justify expansion of staff an increase in marketing effort is needed, which would require more staff.

VI. FURTHER ANALYSIS OF MANAGERIAL DECISION MAKING FOR AN ISS

A discussion of developments in the market for scientific and technical information will give some additional perspectives on the situation of the ISS managers. As previously described, following the decline in batch oriented systems for the dissemination of STI, i.e. SDI services, much activity in the information science field related to investigating the applicability of on-line techniques for STI dissemination. The new technique changed the nature of the information service provided: the subscription orientation was replaced by a demand search orientation which was similar in concept to a "retrospective search", but which had the added capability of providing interaction and modification of the search request during the actual search.

The economics of the new technique was, however, not encouraging. Firstly the hardware itself was relatively costly even for providing a minimal service, and secondly the cost for the information bases and their indices increased significantly. As a consequence of the economic difficulties for small independent centers a market structure developed where the maintenance of the large information bases is done by a relatively small number of "information wholesalers" who also provide the information processing resources needed for searching.[16] The ISS's that are studied here are therefore "information retailers" and for the ISS management this means that their options are limited since software development for the service and information acquisition are done outside the ISS.

The purpose of this section is to discuss possible managerial actions and their effects given the limitations dictated by the structure of the STI market, and given the determinants for staff hiring as described previously.

Different emphasis on marketing

Marketing is sometimes considered the "cure all" for ISS's. It is true that the typical ISS has not enough marketing resources, but if marketing is over emphasized there will be an adverse effect on delivery delays which could mean that what really happens is that resources for marketing and user assistance are needed even more to compensate for the relatively long delivery delay.

Figure 8 shows the result of a simulation run where there is too much emphasis on marketing and assistance. The number of users grows initially as fast as in the reference run (note that the scale in Figure 8 is different) but stops just over 900 and never gets any higher. The number of users does not decline in spite of the adverse effects from the long delivery delay since the effect from marketing and assistance on entry rate is relatively high. The long delivery delay leads to a strong need to expand staff but it also reduces the funder's willingness to support the service. The ISS is also hindered from expansion by the economic constraint since the volume of queries per staff is relatively low. We can almost talk about a "marketing trap" since the long delivery delay will reduce the users propensity to query which means that the marketing effort will have to increase to attract more users to compensate for the low propensity to query. Such an increase, however, would take resources away from production and the delivery delay situation would worsen.

The change made in the simulation model to give Figure 8 encompassed an increase in the indicated need for staff to marketing in loop U5. There are, however, other ways for management to emphasize marketing: the change in allocation of resources (loop Q7) can be made more slowly. This means that the pressure to reallocate staff to production is resisted to a degree. Simulation runs with the ISS model show that such a policy is not adviceable. The immediate effect is that delivery delays increase, and since this is taken as a measure of success there is an increase in staff (loop S10). The expansion is not hindered by a reduction in the funder's willingness to support the service (loop S11) since it takes the funder relatively long time to form an opinion about the quality of the service. The growth in both users (loop U2) and queries (loop Q6) is however slowed down and the economic constraint (loop S12) together with a reduced willingness on part of the funder (loop S11) will soon result in a retraction of staff. After this retraction the behavior of the model is similar to the reference run but the result of the operations during the 240 weeks is worse in both users and queries. Short term successes in terms of staff expansion were counteracted by market responses.

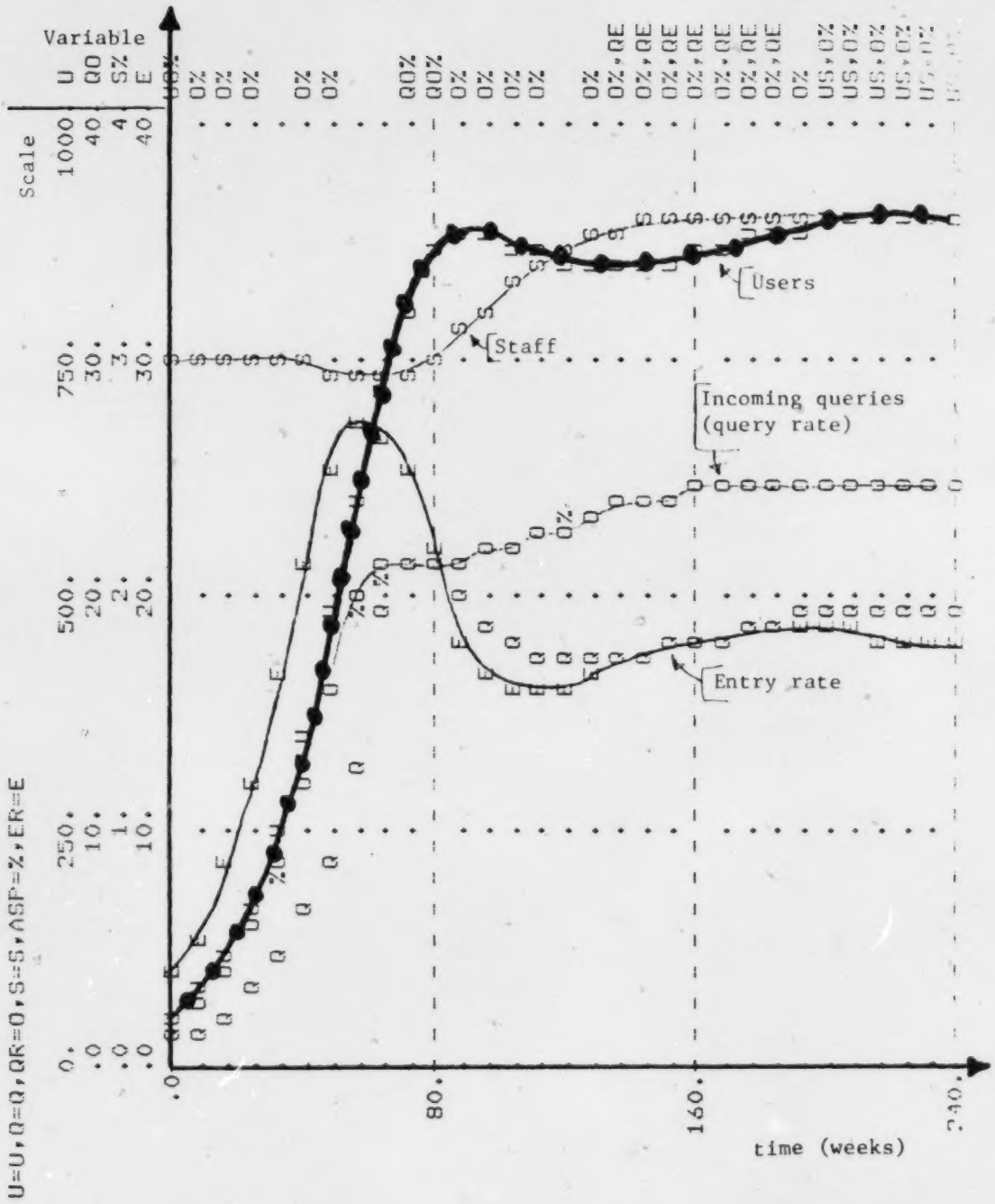

Figure 8.

Result from too much emphasis on marketing.

Changing the size of the user population

The size of the potential market can be more or less given by the institutional setting and it might not be possible to impose discriminatory rules regarding who may and may not become a user. It is common, however, to allow the ISS to extend the potential user population beyond the boundary of its organizational host, and this policy is sometimes applied to increase growth. Simulation runs with the ISS model show that this policy will not give any significant improvement; when the size of the potential market is increased the result is practically identical to the reference run.

Of course, the size of the potential market must be related to the available staff. Typically the number of staff for an ISS, when it is set up, is small which could be taken to indicate that a reduction of the size of the potential market would be better. Simulation runs with the model show that a reduction of the number of potential users from 2000 to 700 gives better result in qualitative terms, i.e. in terms of assistance given and delivery delay, but since there is no visible need for expansion (loop S10) the staff will not be increased. With the staff of three the ISS succeds in attracting 85 percent of the (reduced) potential users.

The actual size of the potential market is difficult to determine exactly. What the simulation results mean is that there is a danger in restricting the market too much, and even if increasing the potential market does not change the quantitative results of the ISS operations much an increase in the market will at least make "normal" expansion possible.

User education

User education has always been considered part of the marketing of ISS's. One reason for this is that an ISS, as many other services, considers it as part of its function to not only help people but also to help them help themselves. Another reason is, of course, that by educating the users about the processes of information dissemination they will not form unrealistic expetations regarding the information search service.

With regard to delivery delay in particular overexpectation has been common. The general tendency to overestimate the speed of computerized processes is part of the reason for this but the ISS's have also reinforced the impression by appealing to this bias in their advertising and marketing. The resulting disappointment effect, when it becomes clear that the ISS does not give "instant access" to the literature, is therefore greater than it needed be.

The simulation model was run with reduced sensitivity to delivery delay on part of the potential users, i.e. delivery delay had less effect on the decision to become a user. The result of this simulation is given in Figure 9, and shows a significant improvement compared to the reference run.

With the potential users being less sensitive to delivery delays they are not discouraged to enter as users and the ISS retains more of its business in spite of a decrease in the propensity to query so that expansion is possible. Staff grows to 5.5 at the end of the 240 weeks and the number of users is 1450. The ISS gets 43.5 search requests per week and 32 new users enter the service weekly.

The growth curve for the number of usersin Figure 9 has a little "kink" around week 65 but the levelling off is not nearly as dramatic as in the reference run. The quantitative results from the simulation are almost as good as a simulation where the funder imposes no constraints on the expansion of staff. In other words the negative effects from overexpectation regarding delivery delay can inhibit growth almost as much as the funder's constraints. For the ISS managers this means that it is very important to design the marketing messages and user education programs so that a realistic picture of what the users can expect in terms of delivery delays is conveyed.

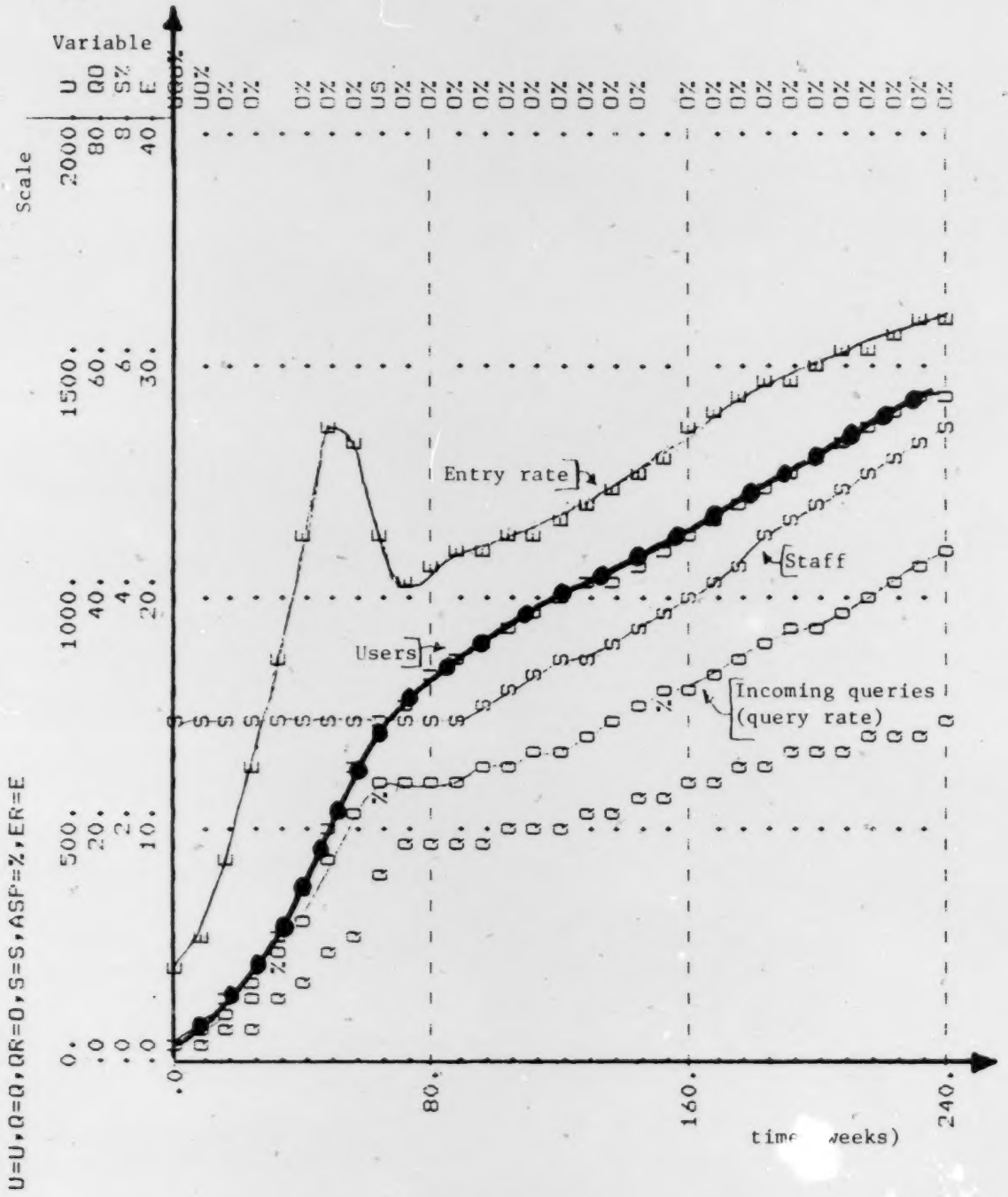

Figure 9.

Reduced effect from delivery delay on entry rate.

VII. CONCLUSIONS

From this analysis of information search services and from the computer simulations of the ISS model we can draw the following conclusions:

The often experienced decline in growth in the number of users can be explained as a natural consequence of market responses to the ISS operations.

The ISS management is in a difficult situation where long delivery delays are needed to justify expansion, but at the same time not wanted sine they have a negative effect on growth. To work for a reduction in the sensitivity to delivery delay, by accurate marketing and user education, is an effective way to alleviate this problem.

Marketing is not a cure-all for ISS's and overemphasis on marketing can be harmful for the growth of the ISS, especially if the funder has a constraint relating to the volume of business per staff in which case there is a potential "marketing trap".

Increasing the size of the potential market might not lead to a significant increase in growth but it is important to have a sufficiently large market so that "normal" growth is secured.

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X APPENDIX

MODEL DESCRIPTION AND MODEL EQUATIONS

MODEL DESCRIPTION

In this appendix the simulation model of a typical ISS is described. The methodology for the simulation study is that of system dynamics[1] which is based on causal analysis and the thrust of which is to study the structure of systems to identify possibilities to improve system performance. Specific reasons favoring this approach for the study of Information Search Services are:

- the interaction between users and the service constitute closed feedback loops
- qualitative behavioral variables and relationships are of great importance as influences on system behavior
- there is a lack of empirical data, especially for parameters relating to evaluation of system performance

The structure of the simulation model is given in Figure 1 which shows both the main activities contained in the model and the parameter groups and assumtions that are inputs to the study.

At the center of Figure 1 is the actual operation of the ISS which provides the service, describable in product and process variables, to the users. The users and potential users evaluate the service and respond by submitting more queries or by deciding to become users respectively.

Management evaluates the operations and decides on resource allocation, resource acquisition, and marketing. Similarly the funder evaluates the operations; he considers both the users' viewpoint and his own criteria and decides on support for the ISS.

---

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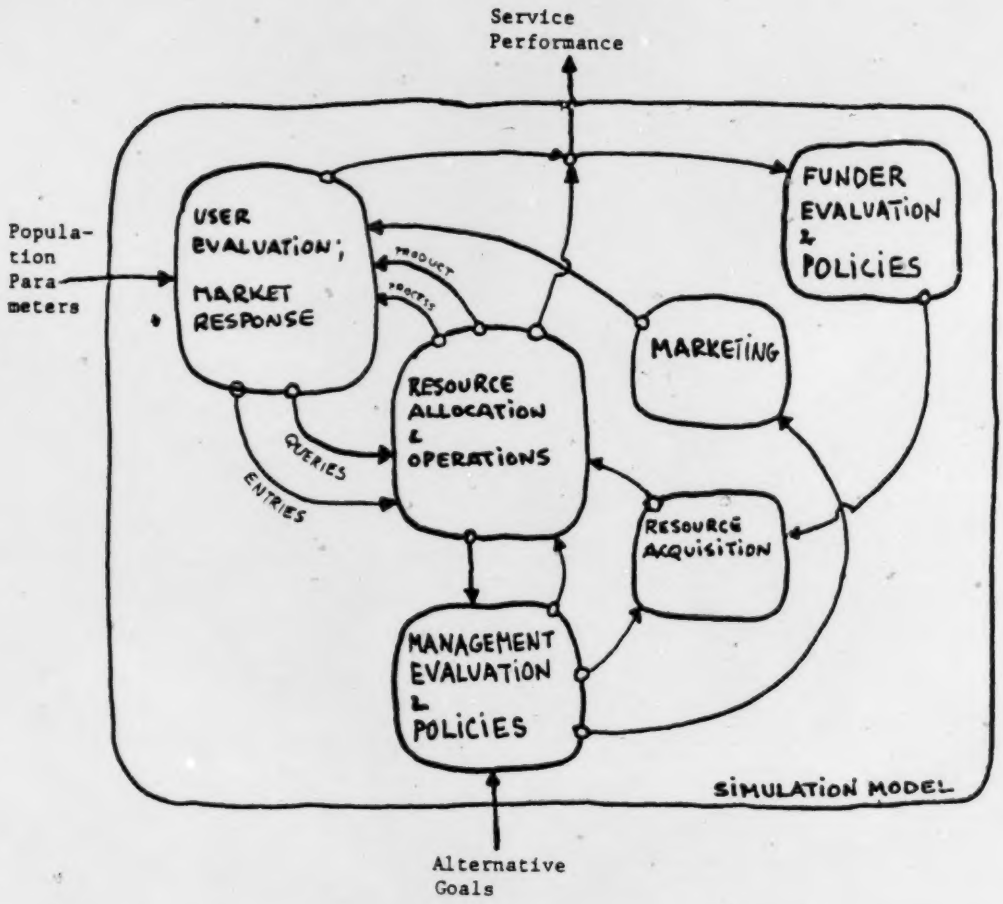


Figure 1.

The structure of the simulation model.

The basic domponents of system dynamics models are levels and rates, represented in Figure 2 by a box and a valve-like symbol respectively. The level corresponds to a stock variable and the rate to a flow variable. Mathematically the level is an integration over time of the rates. A rate is set by a decision which in turn is based on information about the state of the system and external factors.

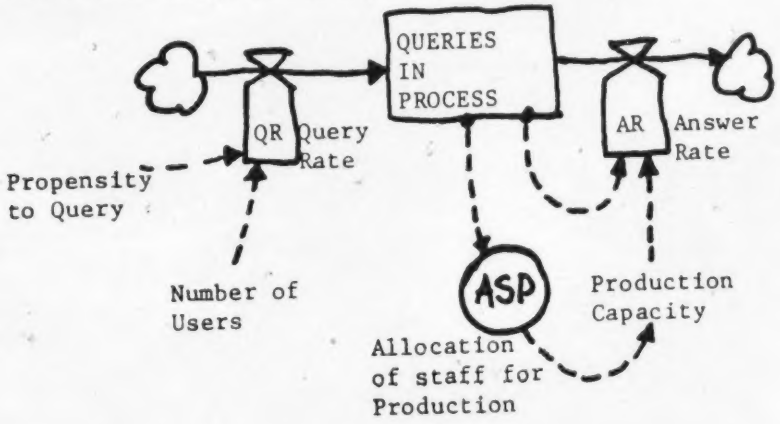


Figure 2.

Example of DYNAMO flow diagram

In Figure 2 the number of queries in process (measured in queries) is increased by the query rate (measured in queries/week) which represents incoming queries, and is decreased by the answer rate (queries/week). If the rate of incoming queries is greater than the answer rate then, over time, there will be a build up of queries in process.

The query rate is determined by 1) the number of users, reflecting their decision to become users (which was, in turn, based on their evaluation of the system), and 2) the propensity to query which represents the users decision to come back.

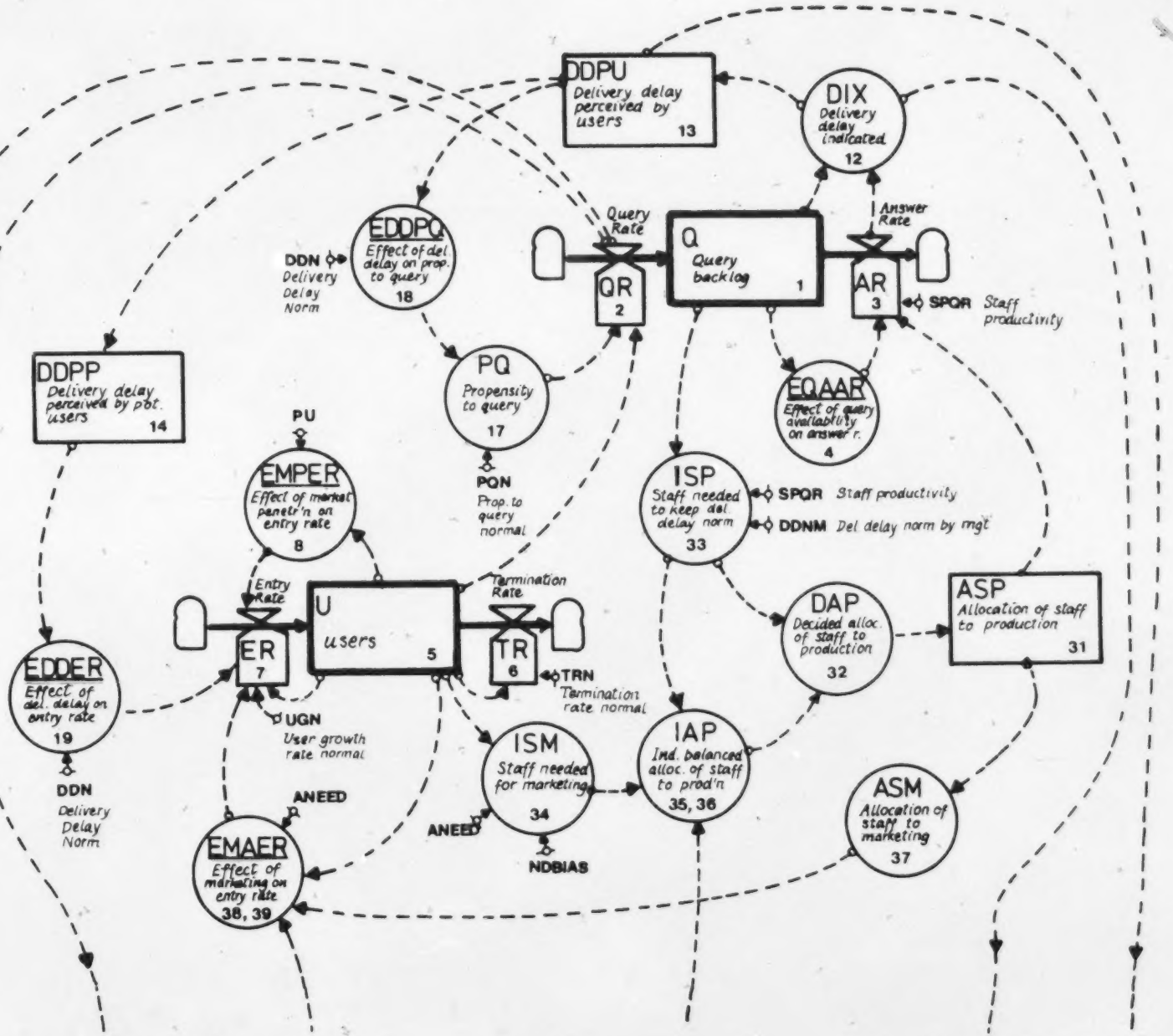
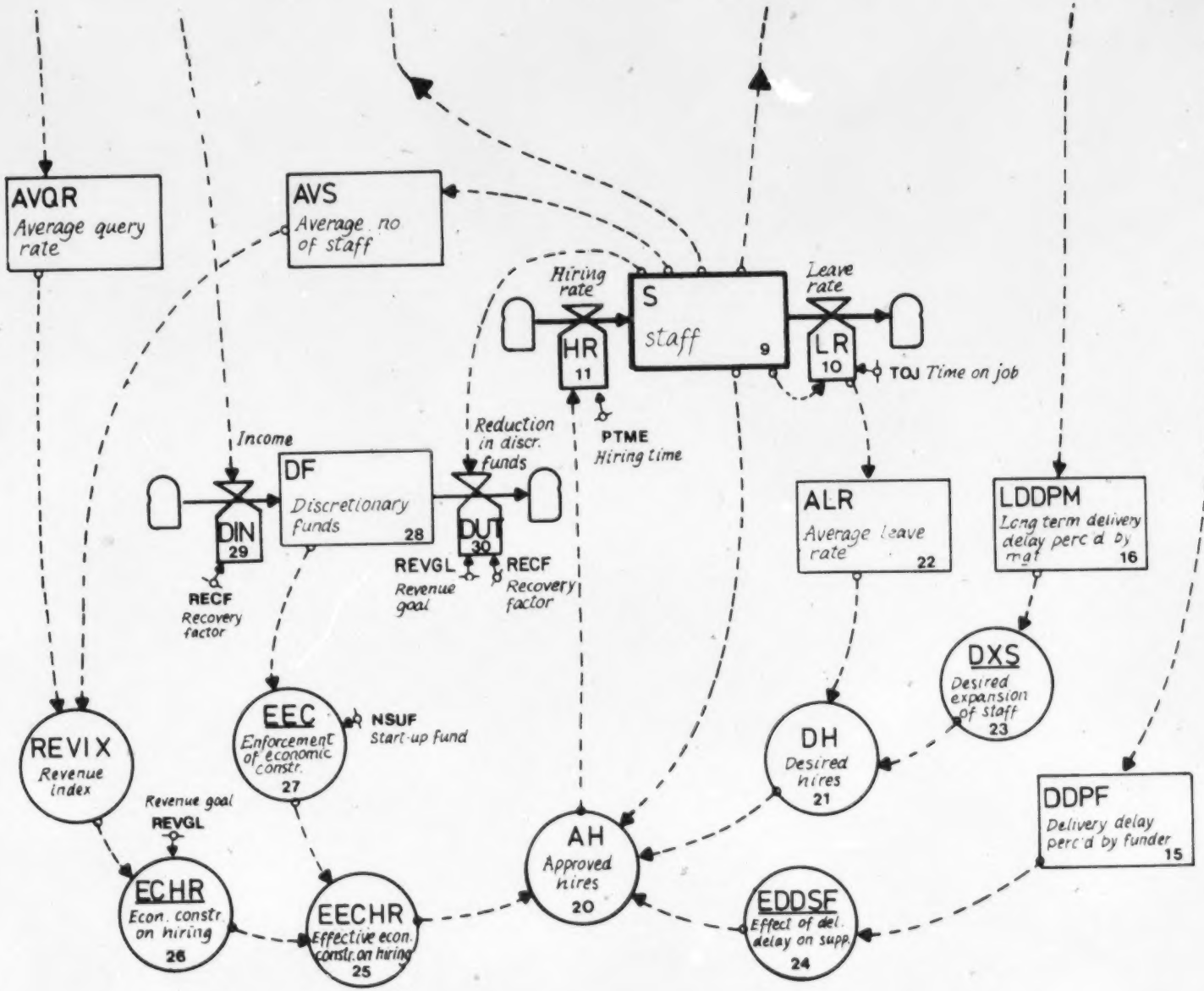


Figure 3. DYNAMO flow diagram of the simulation model ISS2.


AVQR
Average query rate
AVS
Average no of staff
Hiring rate
S
staff
9
Leave rate
HR
11
LR
10
TQJ Time on job
PTME
Hiring time
Income
Reduction in discr. funds
DF
Discretionary funds
28
DIN
29
DUT
30
RECF
Recovery factor
REVGL
Revenue goal
RECF
Recovery factor
ALR
Average leave rate
22
LDDPM
Long term delivery delay perc'd by mgt
16
DXS
Desired expansion of staff
23
EEC
Enforcement of economic constr.
27
NSUF
Start-up fund
REVIX
Revenue index
DH
Desired hires
21
DDPF
Delivery delay perc'd by funder
15
Revenue goal
REVGL
AH
Approved hires
20
ECHR
Econ. constr on hiring
26
EECHR
Effective econ. constr. on hiring
25
EDDSF
Effect of del. delay on supp.
24

41

42

Information links are represented by dashed lines in DYNAMO flow diagrams, as can be seen in the representation of the formulation of the answer rate: The answer rate is a function of how much of the staff resources are allocated to production (i.e. answering queries). The allocation of staff for production is a management decision and is based on the number of queries in process which indicates the need for production capacity. The answer rate, then, is a function of production capacity, which is a function of the allocation decision, which is a function of the number of queries in process, which, finally, is influenced by the answer rate. We have a loop, and since an increase in queries eventually will be counteracted (by the increase in the answer rate) we call this a controlling loop.

The mathematical notation used in the model formulation would represent Figure 2 with the following equations (the 4th and 5th lines not complete):

```
L   QIP.K = QIP.J + (DT)*(QR.JK - AR.JK)
N   QIP = 50
R   QR.KL = PQ * U.K
R   AR.KL = PC.K * [some function preventing QIP from going negative]
A   PC.K = [function of available staff and desired prod. capacity]
C   PQ = 0.02
```

The first equation is a level equation, which is indicated by the 'L', and states that the current number of queries in process (the time postscript K indicates the current time) is equal to the number that were in the previous time period (time postscript J) plus the changes incurred by the query and answer rate in the beriod between time J and time K. A level is given an initial value in a line starting with the letter N.

The 'R' lines specify the rate equations for the time interval between the current time (time index K) and the next timestep (index L). The rate equation can contain constants (such as PQ, in the example above), the current value of system levels (such as U.K, assuming that U is the level of users), or auxiliary variables which vary with time but are not themselves levels. Auxiliaries are, however, practically always a function of other system levels. In the example above production capacity is a function of queries which is a level.

DT is the interval between succeding time steps in the simulation.

Equation by equation listing of the model

Equations 1 - 4 describe how the query backlog changes. It is increased by the query rate which is specified as the number of users multiplied by their propensity to query. The query backlog is reduced by the answer rate which is equal to the number of staff allocated to production times their productivity and a minor effect from query availability. This effect is specified by Table 1.

```
Q.K=Q.J+(DT)*(QR.JK-AR.JK)                                    1, L
Q=QN                                                          1.1, N
     Q       - QUERY BACKLOG (QUERIES)
     QR      - QUERY RATE (QUERIES/WEEK)
     AR      - ANSWER RATE (QUERIES/WEEK)
     QN      - INITIAL NO OF QUERIES

QR.KL=U.K*PQ.K                                                2, R
     QR      - QUERY RATE (QUERIES/WEEK)
     U       - USERS (USERS)
     PQ      - PROPENSITY TO QUERY (QUERIES/WEEK/USER)

AR.KL=ASP.K*SPQR*EQAAR.K                                      3, R
     AR      - ANSWER RATE (QUERIES/WEEK)
     ASP     - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
     SPQR    - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)
     EQAAR   - EFFECT OF QUERY AVAILABILITY ON ANSWER RATE
               (DIM. LESS)
```

Q	EQAAR
0	0
.005	.1
.010	.5
.015	.9
.020	1

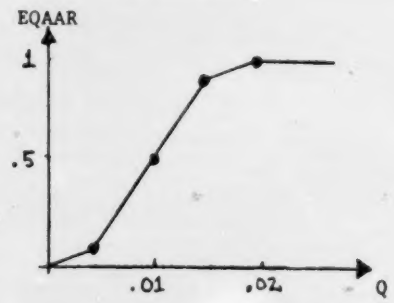


Table 1.

Table 1.

The effect of query availability on answer rate.

```
EQAAR.K=TABHL(TEQAAR,Q.K,0,0.02,0.005)                    4, A
TEQAAR=0/.1/.5/.9/1                                       4.1, T
SPQR=10                                                   4.2, C
```

EQAAR - EFFECT OF QUERY AVAILABILITY ON ANSWER RATE (DIM. LESS)
Q - QUERY BACKLOG (QUERIES)
SPQR - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)

EQAAR is primarily an increase in scheduling delay which leads to a decrease in productivity since the average waiting time will increase when query backlog gets low so that the possibility of deadlock in the matching between queries and information base increases. The effect, however, is minor as reflected by the low values of queries in the table.

Staff productivity is 10 queries/week, which means that a searcher makes on the average 2 searches per working day.

Equations 5 - 7 specify the number of users and how they change. In this model all effects on entry and termination rate have been aggregated into multipliers for the entry rate only. This has been done to keep the model simple. Since we are not interested in keeping track of individual users but rather the flow of users a decrease in entry rate is equivalent to an increase in termination rate.

```
U.K=U.J+(DT)*(ER.JK-TR.JK)                                5, L
U=UN                                                      5.1, N
```

U - USERS (USERS)
ER - ENTRY RATE (USERS/WEEK)
TR - TERMINATION RATE (USERS/WEEK)
UN - INITIAL NO. OF USERS

```
TR.KL=U.K*TRN                                             6, R
TRN=0.02                                                  6.1, C
```

TR - TERMINATION RATE (USERS/WEEK)
U - USERS (USERS)
TRN - TERMINATION RATE NORMAL(FRACTION/WEEK)

```
ER.KL=(U.K)(UGN)(EMAER.K)(EDDER.K)(EMPER.K)               7, R
UGN=0.0374                                                7.1, C
```

ER - ENTRY RATE (USERS/WEEK)
U - USERS (USERS)
UGN - USER GROWTH RATE NORMAL (FRACTION/WEEK)
EMAER - EFFECT OF MARKETING AND ASSISTANCE ON ENTRY RATE (DIM. LESS)
EDDER - EFFECT OF DELIVERY DELAY ON ENTRY RATE (DIM. LESS)
EMPER - EFFECT OF MARKET PENETRATION ON ENTRY RATE (DIM. LESS)

A termination rate normal of 0.02 implies a normal time to remain a user of one year. Such a short time reflects the relative high turnover of people and changes in interest characteristic of an academic setting.

The user growth rate normal is based on the experiences at the University of Georgia Computing Center.[2]

The entry rate is subject to three primary influences: from marketing, expected delivery delay, and market penetration. The effect of market penetration on entryrate EMPER is specified in equation 8 and Table 2.

```
EMPER.K=TABLE(TEMPER,U.K/PU,0,1,0.2)                    8, A
TEMPER=1/1.05/1.1/1.05/.80/0                            8.1, T
PU=2000                                                 8.2, C
     EMPER  - EFFECT OF MARKET PENETRATION ON ENTRY RATE
              (DIM. LESS)
     U      - USERS (USERS)
     PU     - POTENTIAL MARKET (USERS)
```

U/PU	EMPER
0	1
0.2	1.05
0.4	1.1
0.6	1.05
0.8	0.80
1.0	0

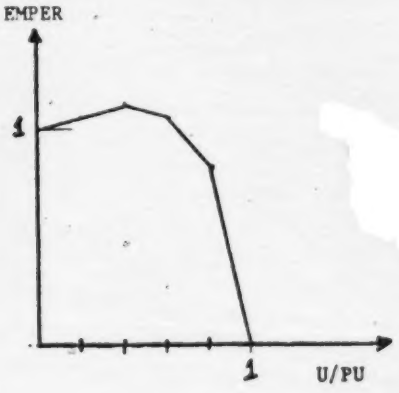


Table 2.

The effect of market penetration on entry rate.

2) Ware, Glenn O. "A General Statistical Model for Estimating Future Demand Levels of Data-Base Utilization Within an Information Retrieval Organization," JASIS, v. 24, n. 4, pp. 261-264.

The effect from market penetration on entry rate depends on the fraction of users to potential users, and represents the increasing difficulty in recruiting new users as more and more potential users have actually decided to become users. The initial increase and subsequent decrease to unity represents an additional effect due to the fact that the probability of a user to come in contact with a potential user, i. e. the word-of-mouth effect, at first increases with an increase in the number of users and then decreases. The final decrease in the value of EMPER is a straightforward saturation effect.

The size of the potential market is 2000 users which means that the typical ISS is part of a reasonably large academic institution.

The effect of delivery delay on entry rate is specified in Equation 19 and Table 3.

```
EDDER.K=TABLE(TEDDER,DDPP.K/DDN,0,3,0.5)                    19. A
TEDDER=1.6/1.47/1/.47/.3/.3/.3                              19.1, T
    EDDER  - EFFECT OF DELIVERY DELAY ON ENTRY RATE
             (DIM. LESS)
    DDPP   - DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
             (DIM. LESS)
    DDN    - DELIVERY-DELAY NORM (WEEKS)
```

DDPP/DDN	EDDER'
0	1.6
0.5	1.47
1.0	1.0
1.5	0.47
2.0	0.3
2.5	0.3
3.0	0.3

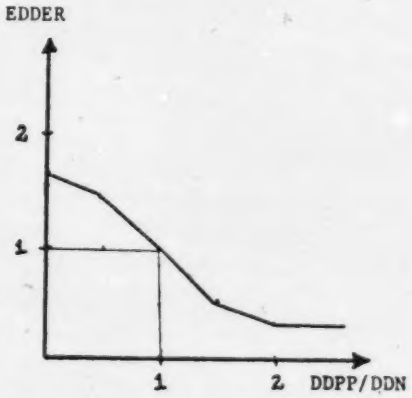


Table 3.

The effect of delivery delay on entry rate.

If the delivery delay is long compared to the standard of the potential users (the delivery delay norm DDN) they will not be as willing to become users. The values in the table show that the maximum effect of short delivery delay is a 60 percent increase in the entry rate, and that there are decreasing returns to improvements in delivery delay.

The value of DDN is 0.5 which means that the potential users consider a delivery delay of half a week normal.

Equation 38 determines the need for user assistance as the number of users times their need for assistance ANEED. The value of ANEED is 0.001 staff per user which means that, assuming a 40 hour work week and 50 work weeks per year, that a user requires 2 hours of staff time to be satisfied.

The ratio of needed to available assistance determines the effect of marketing and assistance on entry rate EMAER as specified in Equation 39 and Table 4. When there is a need for more assistance that what is available the entry rate will be less than normal, and when there is more staff available than what is needed to assist users their user oriented activities become marketing. There is no clear distinction between marketing and assistance activities for an ISS, although there is such a thing as "pure" marketing.

The effect from marketing and assistance is assumed to be greater than that from delivery delay, and Table 4 shows that the entry rate could be almost doubled if there were unlimited resources for marketing. The table also shows that an allocation of staff to marketing gives increasing returns to scale.

```
ASTND.K=U.K*ANEED                                          38, A
ANEED=0.001                                                38.1, C
    ASTND  - ASSISTANCE NEEDED (STAFF)
    U      - USERS (USERS)
    ANEED  - ASSISTANCE NEEDED PER USER (STAFF/
             USER)

EMAER.K=TABLE(TEMAER,ASTND.K/ASM.K,0,3,0.25)               39, A
TEMAER=2/1.55/1.3/1.1/1/.81/.7/.62/.56/.5/.45/.42/         39.1, T
  .38
    EMAER  - EFFECT OF MARKETING AND ASSISTANCE ON ENTRY
             RATE (DIM. LESS)
    ASTND  - ASSISTANCE NEEDED (STAFF)
    ASM    - ALLOCATION OF STAFF TO MARKETING AND
             ASSISTANCE (STAFF)
```

ASTND/ASM	EMAER
0	2.0
0.25	1.55
0.5	1.3
0.75	1.1
1.0	1.0
1.25	0.81
1.5	0.7
1.75	0.62
2.0	0.56
2.25	0.5
2.5	0.45
2.75	0.42
3.0	0.38

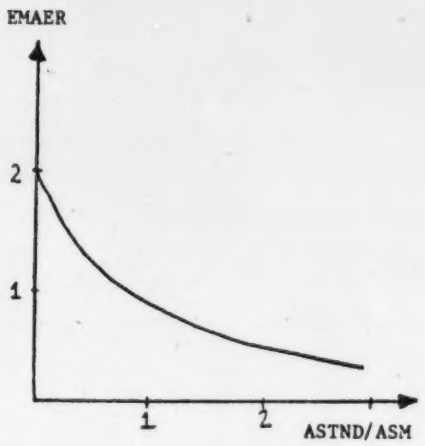


Table 4.

The effect of marketing and assistance on entry rate.

Equations 12 - 16 describe the delivery delay and how it is perceived by the different decision-makers. The users' perceived delivery delay is a delayed version of the indicated delivery delay which is equal to the query backlog divided by the answer rate (Equation 12). The users' perception time is 13 weeks which is a maturing time for their own experience, and it is assumed that it takes about that long a time to form a definite opinion regarding the "true" value of the delay time.

The potential users and the funder have not a first hand experience of the service so their perception of the delivery delay is based on the users'. The perception time for the potential users is 26 weeks, and for the funder 40 weeks.

Management does not have to rely on the users' perception to find out about the delivery delay, so their long term recognized delivery delay is a 26 week exponential average of the indicated delivery delay DIX.

```
DIX.K=Q.K/AR.JK                                          12, A
    DIX     - DELIVERY DELAY INDICATED (WEEKS)
    Q       - QUERY BACKLOG (QUERIES)
    AR      - ANSWER RATE (QUERIES/WEEK)

DDPU.K=SMOOTH(DIX.K,UPT)                                 13, A
UPT=13                                                   13.1, C
    DDPU    - DELIVERY DELAY PERCEIVED BY USERS (DIM.
              LESS)
    DIX     - DELIVERY DELAY INDICATED (WEEKS)
    UPT     - USERS' PERCEPTION TIME (WEEKS)
```

```
DDPP.K=SMOOTH(DDPU.K,PPT)                                    14, A
PPT=26                                                       14.1, C
    DDPP   - DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
             (DIM. LESS)
    DDPU   - DELIVERY DELAY PERCEIVED BY USERS (DIM.
             LESS)
    PPT    - POTENTIAL USERS' PERCEPTION TIME (WEEKS)

DDPF.K=SMOOTH(DDPU.K,FPT)                                    15, A
FPT=40                                                       15.1, C
    DDPF   - DELIVERY DELAY PERCEIVED BY FUNDER (WEEKS)
    DDPU   - DELIVERY DELAY PERCEIVED BY USERS (DIM.
             LESS)
    FPT    - FUNDER'S PERCEPTION TIME (WEEKS)

LDDPM.K=SMOOTH(DIX.K,LMPT)                                   16, A
LMPT=26                                                      16.1, C
    LDDPM  - LONG TERM DELIVERY DELAY PERCEIVED BY
             MANAGEMENT (WEEKS)
    DIX    - DELIVERY DELAY INDICATED (WEEKS)
    LMPT   - MANAGEMENT'S LONG TERM PERCEPTION TIME
             (WEEKS)
```

The effect of delivery delay on the entry rate has already been discussed. In addition to this effect delivery delay also has an impact on the propensity to query, i. e. it can discourage return use without making the user leave the service. The effect of delivery delay on the propensity to query is defined by Equation 18 and Table 5. The relative flatness of the curve describing EDDPQ is explained by the fact that EDDPQ is an additional effect on the propensity to query which is primarily a characteristic of the user population. The normal propensity to query PQN is 0.035 queries per week and user which means an average of 1.8 queries per year or 29 weeks between queries. This value is consistent with published studies regarding the use of on-line search services.[3]

```
PQ.K=PQN*EDDPQ.K                                             17, A
    PQ     - PROPENSITY TO QUERY (QUERIES/WEEK/USER)
    PQN    - NORMAL PROPENSITY TO QUERY (QUERIES/WEEK/
             USER)
    EDDPQ  - EFFECT OF DELIVERY DELAY ON THE PROPENSITY
             TO QUERY (DIM. LESS)

PQN=0.035
```

3) Ljungberg, Sixten. "The use of computers in information and documentation," (In Swedish), T. Document. (The Scandinavian Documentation Journal), v, 31, n. 6 (1975), pp. 74-80.

DDPU/DDN	EDDPQ
0	1.5
0.5	1.25
1.0	1.0
1.5	0.8
2.0	0.65
2.5	0.57
3.0	0.5

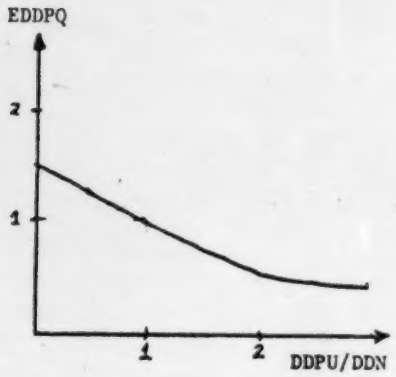


Table 5.

The effect of delivery delay on the propensity to query.

```
EDDPQ.K=TABLE(TEDDPQ,DDPU.K/DDN,0,3,0.5)                    18, A
TEDDPQ=1.5/1.25/1/.8/.65/.57/.5                             18.1, T
    EDDPQ   - EFFECT OF DELIVERY DELAY ON THE PROPENSITY
              TO QUERY (DIM. LESS)
    DDPU    - DELIVERY DELAY PERCEIVED BY USERS (DIM.
              LESS)
    DDN     - DELIVERY DELAY NORM (WEEKS)
```

Equations 9 - 11 describe the number of staff and how it is changed. The hiring rate is equal to approved hires AH divided by the hiring time which is 26 weeks.

The leave rate LR is formulated as the number of staff divided by the average time they stay on the job TOJ which is 200 weeks.

```
S.K=S.J+(DT)*(HR.JK-LR.JK)                                  9, L
S=SN                                                        9.1, N
    S       - STAFF (STAFF)
    HR      - HIRING RATE (STAFF/WEEK)
    LR      - LEAVE RATE (STAFF/WEEK)
    SN      - INITIAL NO. OF STAFF

LR.KL=S.K/TOJ                                               10, R
TOJ=200                                                     10.1, C
    LR      - LEAVE RATE (STAFF/WEEK)
    S       - STAFF (STAFF)
    TOJ     - TIME ON JOB (WEEKS)

HR.KL=AH.K/PTME                                             11, R
PTME=26                                                     11.1, C
    HR      - HIRING RATE (STAFF/WEEK)
    AH      - APPROVED HIRES (STAFF)
    PTME    - HIRING TIME (WEEKS)
```

The hiring decision is influenced both by economic concerns and the performance of the ISS in terms of delivery delay. The decision is described in Equations 20 - 27.

The approved hires AH specified in Equation 20 are a function of the desired hires DH and the funder's willingness to support the service as well as the economic constraint.

In Equation 21 the desired hires DH is formulated as the sum of a compensation for leaving staff, which is calculated in Equation 22, and a desired expansion of staff which depends on the long term delivery delay situation perceived by management as defined in Equation 23 and Table 6.

```
AH.K=(DH.K*EDDSF.K)-EECHR.K*S.K                                    20, A
    AH      - APPROVED HIRES (STAFF)
    DH      - DESIRED HIRES (STAFF)
    EDDSF   - EFFECT OF DELIVERY DELAY ON THE SUPPORT
              FROM FUNDER (DIM. LESS)
    EECHR   - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
              (DIM. LESS)
    S       - STAFF (STAFF)

DH.K=(ALR.K*PTME)+DXS.K*S.K                                        21, A
    DH      - DESIRED HIRES (STAFF)
    ALR     - AVERAGE LEAVE RATE (STAFF/WEEK)
    PTME    - HIRING TIME (WEEKS)
    DXS     - DESIRED EXPANSION OF STAFF(DIM. LESS)
    S       - STAFF (STAFF)

ALR.K=SMOOTH(LR.JK,LMPT)                                           22, A
    ALR     - AVERAGE LEAVE RATE (STAFF/WEEK)
    LR      - LEAVE RATE (STAFF/WEEK)
    LMPT    - MANAGEMENT'S LONG TERM PERCEPTION TIME
              (WEEKS)
```

LDDPM/LDDNM	DXS
0	-20%
.5	-15%
1	0
1.5	20%
2	35%
2.5	45%
3	50%

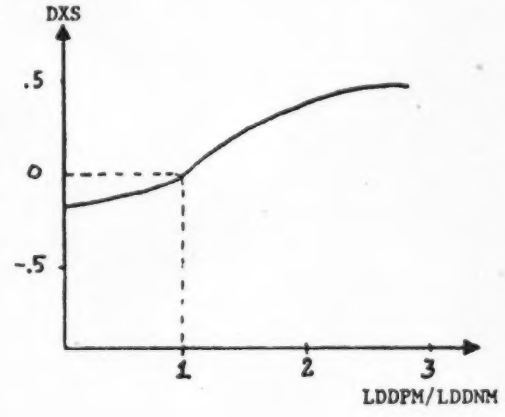


Table 6.

Desired expansion of staff.

```
DXS.K=TABLE(TDXS,LDDPM.K/LDDNM,0,3,0.5)                    23, A
LDDNM=0.5                                                   23.1, C
TDXS=-.2/-.15/0/.2/.35/.45/.5                               23.2, T
    DXS     - DESIRED EXPANSION OF STAFF(DIM. LESS)
    LDDPM   - LONG TERM DELIVERY DELAY PERCEIVED BY
              MANAGEMENT (WEEKS)
    LDDNM   - LONG TERM DELIVERY DELAY NORM HELD BY
              MANAGEMENT (WEEKS)
```

The formulation of the desired expansion of staff DXS is fairly conservative as can be seen from Table 6. The conservatism is also manifested by the choice of LDDNM which is set to 0.5 weeks - the same as the delivery delay norm held by the market DDN. It is assumed that the ISS management makes "responsible" requests for expansion so that when the long term delivery delay perceived by management LDDPM is shorter than the norm LDDNM management will request less resources.

Equation 24 and Table 7 show the effect of delivery delay on the funder's willingness to support the ISS. If the delivery delay perceived by the funder is shorter than the market norm DDN then EDDSF will be equal to one which means that it will not have any adverse effect on the number of approved hires AH. The funder reacts, however, by sustained long delivery delays by not granting the full expansion of staff requested by the ISS management.

```
EDDSF.K=TABHL(TEDDSF,DDPF.K/DDN,1,3,0.5)                   24, A
TEDDSF=1/.75/.50/.40/.35                                    24.1, T
    EDDSF   - EFFECT OF DELIVERY DELAY ON THE SUPPORT
              FROM FUNDER (DIM. LESS)
    DDPF    - DELIVERY DELAY PERCEIVED BY FUNDER (WEEKS)
    DDN     - DELIVERY DELAY NORM (WEEKS)
```

DDPF/DDN	EDDSF
1.0	1.0
1.5	.75
2.0	.50
2.5	.40
3.0	.35

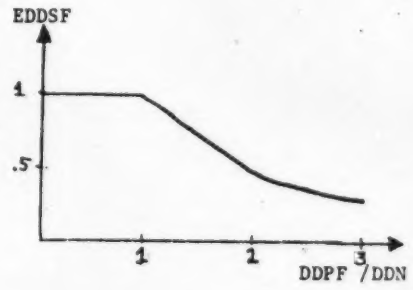


Table 7.

The effect of delivery delay on the support from funder.

From the beginning it has been common to charge the users of ISS's for the service, and a recent discussion about developments in the field of scientific and technical information dissemination indicates that economic considerations are becoming increasingly important.[4] For the simulation model these considerations are described in Equations 25 - 27 and in Tables 8 and 9.

The economic constraint on hiring ECHR is a function of the ratio between the revenue goal REVGL, which is expressed in queries per week per staff, and the revenue index REVIX which is the average number of queries per week per staff achieved by the ISS. The funder expects a certain volume of business per staff and unless the goal is satisfied he will want to reduce the number of staff. The reduction in staff is given in Equation 26 and Table 8.

```
EECHR.K=ECHR.K*EEC.K                                          25, A
    EECHR  - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
             (DIM. LESS)
    ECHR   - ECONOMIC CONSTRAINT ON HIRING (DIM. LESS)
    EEC    - ENFORCEMENT OF ECONOMIC CONSTRAINT (DIM.
             LESS)

ECHR.K=TABHL(TECHR,REVGL/REVIX.K,1,1.5,0.1)                   26, A
TECHR=0/.08/.15/.20/.23/.25                                   26.1, T
REVGL=8                                                       26.2, C
    ECHR   - ECONOMIC CONSTRAINT ON HIRING (DIM. LESS)
    REVGL  - REVENUE GOAL (QUERIES/WEEK/STAFF)
    REVIX  - REVENUE INDEX (DIM. LESS)
```

REVGL/REVIX	ECHR
1.0	0
1.1	.08
1.2	.15
1.3	.20
1.4	.23
1.5	.25

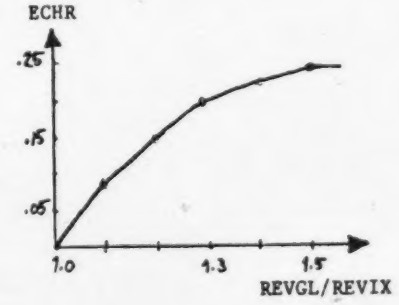


Table 8

The economic constraint on hiring.

4) Schwarz, Stephan. "Information Services to Industry: The Role of the Technological University Library," J. Doc., v. 32, n. 1 (March 1976), pp. 1-16.

In the extreme case, when the volume of business per staff is 30 percent or more below the goal the funder wants a 25 percent reduction in staff.

For a reasonable start-up time it is assumed that the funder is willing to accept that the number of queries per week and staff will not be equal to his goal, and he would be willing to pay the full cost for the ISS. In the simulation model this is represented as a discretionary fund which is depleted by a certain amount weekly unless the volume of business is at the revenue goal. The enforcement of the economic constraint EEC is a function of how much money is left in the discretionary fund relative to the initial amount NSUF. EEC is defined in Equation 27 and Table 9.

```
EEC.K=TABHL(TEEC,DF.K/NSUF,0,1,0.25)                    27, A
TEEC=1/.45/.20/.07/0                                    27.1, T
    EEC     - ENFORCEMENT OF ECONOMIC CONSTRAINT (DIM.
              LESS)
    DF      - DISCRETIONARY FUNDS (DOLLARS)
    NSUF    - INITIAL START-UP FUND (DOLLARS)
```

DF/NSUF	EEC
0	1
.25	.45
.50	.20
.75	.07
1.0	0

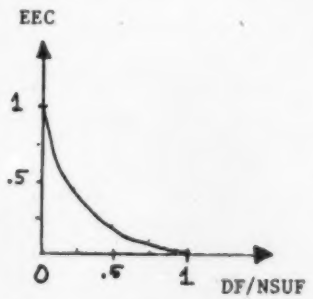


Table 9.

The enforcement of the economic constraint.

If the discretionary fund is not depleted at all the economic constraint will not be enforced at all, and if the discretionary fund is used up the constraint will be enforced fully.

The discretionary funds DF are defined in Equation 28 and they are a measure of the economic viability of the ISS. The initial value for these funds NSUF reflects the funder's patience; with REVGL=8 and an NSUF of 15000 he is willing to wait of the order of a year and a half before the revenue goal is achieved (the recovery factor is assumed to be $10 per query).

DF is increased by a certain amount per answered query RECF, and this recovery factor is set to $10 which means that the ISS will have to charge the users on the order of $30 - 40 per query unless the cost of the searches are paid for by the funder. The formulation for the increase in discretionary funds is given in Equation 29.

The reduction in the discretionary funds is defined in Equation 30. DUT is not a flow of real dollars, typically, but is more like a reduction in the managerial discression. The bookkeeping of the ISS is usually subordinated the funder's so "right to use" is more important than actual balances.

```
DF.K=DF.J+(DT)*(DIN.JK-DUT.JK)                          28, L
DF=NSUF                                                 28.1, N
NSUF=15000                                              28.2, C
    DF      - DISCRETIONARY FUNDS (DOLLARS)
    DIN     - INCOME (DOLLARS/WEEK)
    DUT     - REDUCTION IN DISCRETIONARY FUNDS (DOLLARS/WEEK)
    NSUF    - INITIAL START-UP FUND (DOLLARS)

DIN.KL=AR.JK*RECF                                       29, R
RECF=10                                                 29.1, C
    DIN     - INCOME (DOLLARS/WEEK)
    AR      - ANSWER RATE (QUERIES/WEEK)
    RECF    - RECOVERY FACTOR (DOLLARS/QUERY)

DUT.KL=S.K*REVGL*RECF                                   30, R
    DUT     - REDUCTION IN DISCRETIONARY FUNDS (DOLLARS/WEEK)
    S       - STAFF (STAFF)
    REVGL   - REVENUE GOAL (QUERIES/WEEK/STAFF)
    RECF    - RECOVERY FACTOR (DOLLARS/QUERY)
```

The resource allocation decision is described by Equations 31 - 37. It lies in the nature of a service like an ISS to have a reactive resource allocation policy: management tries to spend some resources on marketing but when queries come in they have to be answered. Changes in the allocation cannot be done immediately but the allocation change time ACT is relatively short: 2 weeks. Equation 31 describes the actual allocation of staff to production as a delayed version of the decided allocation DAP which is defined in Equation 32. DAP is the actual decision about how much staff should be allocated to production. The ISS management allocates enough staff to production to keep the delivery delay at the norm until there is a conflict from the pressure to allocate some resources to assistance also. To keep the delivery delay norm ISP staff is needed as calculated by Equation 33.

```
ASP.K=SMOOTH(DAP.K,ACT)                                    31, A
ACT=2                                                      31.1, C
    ASP     - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
    DAP     - DECIDED ALLOCATION OF STAFF TO PRODUCTION
              (STAFF)
    ACT     - ALLOCATION CHANGE TIME (WEEKS)

DAP.K=MIN(IAP.K,ISP.K)                                     32, A
    DAP     - DECIDED ALLOCATION OF STAFF TO PRODUCTION
              (STAFF)
    IAP     - INDICATED BALANCED ALLOCATION OF STAFF TO
              PRODUCTION (STAFF)
    ISP     - STAFF NEEDED FOR PRODUCTION TO KEEP
              DELIVERY DELAY NORM (STAFF)

ISP.K=Q.K/(SPQR*DDNM)                                      33, A
DDNM=0.5                                                   33.1, C
    ISP     - STAFF NEEDED FOR PRODUCTION TO KEEP
              DELIVERY DELAY NORM (STAFF)
    Q       - QUERY BACKLOG (QUERIES)
    SPQR    - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)
    DDNM    - DELIVERY DELAY NORM HELD BY MANAGEMANT
              (WEEKS)
```

The pressure to allocate staff to assistance and marketing is recognized in Equation 34 which defines the staff needed for marketing ISM. ISM is defined as the number of users times the need for assistance in terms of staff per user. There is also a bias factor NDBIAS which represents the ability of the ISS management to recognize the need for assistance properly.

```
ISM.K=U.K*ANEED*NDBIAS                                    34, A
NDBIAS=1                                                  34.1, C
    ISM     - STAFF NEEDED FOR MARKETING (STAFF)
    U       - USERS (USERS)
    ANEED   - ASSISTANCE NEEDED PER USER (STAFF/
              USER)
    NDBIAS  - BIAS IN RECOGNIZING NEED FOR MARKETING AND
              ASSISTANCE (DIM. LESS)

IFP.K=ISP.K/(ISP.K+ISM.K)                                 35, A
    IFP     - INDICATED BALANCED FRACTIONAL ALLOCATION OF
              STAFF TO PRODUCTION (FRACTION)
    ISP     - STAFF NEEDED FOR PRODUCTION TO KEEP
              DELIVERY DELAY NORM (STAFF)
    ISM     - STAFF NEEDED FOR MARKETING (STAFF)

IAP.K=IFP.K*S.K                                           36, A
    IAP     - INDICATED BALANCED ALLOCATION OF STAFF TO
              PRODUCTION (STAFF)
    IFP     - INDICATED BALANCED FRACTIONAL ALLOCATION OF
              STAFF TO PRODUCTION (FRACTION)
    S       - STAFF (STAFF)

ASM.K=S.K-ASP.K                                           37, A
    ASM     - ALLOCATION OF STAFF TO MARKETING AND
              ASSISTANCE (STAFF)
    S       - STAFF (STAFF)
    ASP     - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
```

The number of staff needed for production and for marekting and assistance respectively are considered in calculating a balanced allocation of staff which is done in Equations 35 and 36.

The staff resources not allocated to production are available for marekting and assistance activities, as described in Equation 37.

Equations 40 - 47 define performance and operational measures which can help in assessing the "results" of different simulation runs. They will not be described further.

```
SAR.K=SAR.J+(DT)*(AR.JK)                                    40, L
SAR=NSAR                                                    40.1, N
NSAR=0                                                      40.2, C
    SAR     - TOTAL NO. OF ANSWERED QUERIES (QUERIES)
    AR      - ANSWER RATE (QUERIES/WEEK)

SER.K=SER.J+(DT)*(ER.JK)                                    41, L
SER=NSER                                                    41.1, N
NSER=0                                                      41.2, C
    SER     - TOTAL NO. OF USERS (USERS)
    ER      - ENTRY RATE (USERS/WEEK)

SRVIX.K=EDDER.K*EMAER.K                                     42, A
    SRVIX   - SERVICE INDEX
    EDDER   - EFFECT OF DELIVERY DELAY ON ENTRY RATE
              (DIM. LESS)
    EMAER   - EFFECT OF MARKETING AND ASSISTANCE ON ENTRY
              RATE (DIM. LESS)

NER.K=(ER.JK-TR.JK)                                         43, A
    NER     - NET ENTRY RATE (USERS/WEEK)
    ER      - ENTRY RATE (USERS/WEEK)
    TR      - TERMINATION RATE (USERS/WEEK)

YPUG.K=(SMOOTH(NER.K,52))*(5200)/U.K                        44, A
    YPUG    - YEARLY PERCENTAGE GROWTH IN USERS
    NER     - NET ENTRY RATE (USERS/WEEK)
    U       - USERS (USERS)

QPUG.K=(SMOOTH(NER.K,12))*(1200)/U.K                        45, A
    QPUG    - QUARTERLY PERCENTAGE GROWTH IN USERS
    NER     - NET ENTRY RATE (USERS/WEEK)
    U       - USERS (USERS)

AGOWL.K=AGOWL.J+(DT)*(GWR.JK)                               46, L
AGOWL=NAGOWL                                                46.1, N
NAGOWL=0                                                    46.2, C
    AGOWL   - ACCUMULATED GOODWILL
    GWR     - GOODWILL RATE

GWR.KL=SRVIX.K                                              47, R
    GWR     - GOODWILL RATE
    SRVIX   - SERVICE INDEX
```

The performance measure used to assess the revenue situation of the ISS, which is affecting the economic constraint on hiring (in Equation 26), is the revenue index REVIX described in Equation 48. It is the ratio of the average query rate AVQR, defined in Equation 49, and the average number of staff, defined in Equation 50.

```
REVIX.K=AVQR.K/AVS.K                                        48, A
    REVIX   - REVENUE INDEX (DIM. LESS)
    AVQR    - AVERAGE QUERY RATE (QUERIES/WEEK)
    AVS     - AVERAGE STAFF (STAFF)

AVQR.K=SMOOTH(QR.JK,STRA)                                   49, A
    AVQR    - AVERAGE QUERY RATE (QUERIES/WEEK)
    QR      - QUERY RATE (QUERIES/WEEK)
    STRA    - SMOOTHING TIME FOR REVENUE ASSESSMENT
              (WEEKS)

AVS.K=SMOOTH(S.K,STRA)                                      50, A
STRA=26                                                     50.1, C
    AVS     - AVERAGE STAFF (STAFF)
    S       - STAFF (STAFF)
    STRA    - SMOOTHING TIME FOR REVENUE ASSESSMENT
              (WEEKS)
```

This completes the description of the model equations. To run the model initial values for Q, S, and U and control "cards" are needed, these are given in the following.

INITIAL CONDITIONS AND CONTROL CARDS

```
QN=1                                                        50.5, C
SN=3                                                        50.6, C
UN=50                                                       50.7, C
DT=.2                                                       50.8, C
TIME=NTIME                                                  50.9, N
NTIME=0                                                     51.1, C
LENGTH=0                                                    51.2, C
PLTPER=8                                                    51.3, C
    QN      - INITIAL NO OF QUERIES
    SN      - INITIAL NO. OF STAFF
    UN      - INITIAL NO. OF USERS
```

```
PLOT  U=U/Q=Q,QR=Q/S=S,ASP=%/ER=E                              51.4
    U       - USERS (USERS)
    Q       - QUERY BACKLOG (QUERIES)
    QR      - QUERY RATE (QUERIES/WEEK)
    S       - STAFF (STAFF)
    ASP     - ALLOCATION OF STAFF TO PRODUCTION (STAFF)

PLOT  EDDPQ=1,EDDER=2,EMAER=3,EMPER=4(0,2)/DXS=                51.5
  X(-1,1)/EECHR=C,EDDSF=S(0,1)
    EDDPQ   - EFFECT OF DELIVERY DELAY ON THE PROPENSITY
              TO QUERY (DIM. LESS)
    DXS     - DESIRED EXPANSION OF STAFF(DIM. LESS)
    EECHR   - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
              (DIM. LESS)
    EDDSF   - EFFECT OF DELIVERY DELAY ON THE SUPPORT
              FROM FUNDER (DIM. LESS)

PRTPER=48                                                      51.7. C

PRINT 1)U/2)Q/3)S/4)QR/5)HR/6)ER                               51.8
    U       - USERS (USERS)
    Q       - QUERY BACKLOG (QUERIES)
    S       - STAFF (STAFF)
    QR      - QUERY RATE (QUERIES/WEEK)
    HR      - HIRING RATE (STAFF/WEEK)
    ER      - ENTRY RATE (USERS/WEEK)

PRINT 1)SAR/2)SER/3)EECHR/4)YPUG/5)QPUG/6)AGOWL                 51.9
    SAR     - TOTAL NO. OF ANSWERED QUERIES (QUERIES)
    SER     - TOTAL NO. OF USERS (USERS)
    EECHR   - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
              (DIM. LESS)
    YPUG    - YEARLY PERCENTAGE GROWTH IN USERS
    QPUG    - QUARTERLY PERCENTAGE GROWTH IN USERS
    AGOWL   - ACCUMULATED GOODWILL
```

MODEL EQUATIONS

SEP 13 1976

```
list
00010 *  ISS2
00020 NOTE
00030 NOTE
00040 L  Q.K=Q.J+(DT)*(QR.JK-AR.JK)
00050 N  Q=QN
00060 R  QR.KL=U.K*PQ.K
00070 R  AR.KL=ASP.K*SPQR*EQAAR.K
00080 A  EQAAR.K=TABHL(TEQAAR,Q.K,0,0.02,0.005)
00090 T  TEQAAR=0/.1/.5/.9/1
00100 C  SPQR=10
00110 L  U.K=U.J+(DT)*(ER.JK-TR.JK)
00120 N  U=UN
00130 R  TR.KL=U.K*TRN
00140 C  TRN=0.02
00150 R  ER.KL=(U.K)(UGN)(EMAER.K)(EDDER.K)(EMPER.K)
00160 C  UGN=0.0374
00170 A  EMPER.K=TABLE(TEMPER,U.K/PU,0,1,0.2)
00180 T  TEMPER=1/1.05/1.1/1.05/.80/0
00190 C  PU=2000
00200 L  S.K=S.J+(DT)*(HR.JK-LR.JK)
00210 N  S=SN
00220 R  LR.KL=S.K/TOJ
00230 C  TOJ=200
00240 R  HR.KL=AH.K/PTME
00250 C  PTME=26
00260 NOTE
00270 NOTE DELIVERY DELAY ETC.
00280 NOTE
00290 A  DIX.K=Q.K/AR.JK
00300 A  DDPU.K=SMOOTH(DIX.K,UPT)
00310 C  UPT=13
00320 A  DDPP.K=SMOOTH(DDPU.K,PPT)
00330 C  PPT=26
00340 A  DDPF.K=SMOOTH(DDPU.K,FPT)
00350 C  FPT=40
00360 A  LDDPM.K=SMOOTH(DIX.K,LMPT)
00370 C  LMPT=26
00380 NOTE
00390 NOTE  EFFECTS OF DD
00400 NOTE
00410 A  PQ.K=PQN*EDDPQ.K
00420 A  EDDPQ.K=TABLE(TEDDPQ,DDPU.K/DDN,0,3,0.5)
00430 T     TEDDPQ=1.5/1.25/1/.8/.65/.57/.5
00440 A  EDDER.K=TABLE(TEDDER,DDPP.K/DDN,0,3,0.5)
00450 T  TEDDER=1.6/1.47/1/.47/.3/.3/.3
```

```
00460 NOTE
00470 NOTE LONG TERM DECISIONS
00480 NOTE
00490 A  AH.K=(DH.K*EDDSF.K)-EECHR.K*S.K
00500 A  DH.K=(ALR.K*PTME)+DXS.K*S.K
00510 A  ALR.K=SMOOTH(LR.JK,LNPT)
00520 A  DXS.K=TABLE(TDXS,LDDPM.K/LDDNM,0,3,0.5)
00530 C  LDDNM=0.5
00540 T  TDXS=-.2/-.15/0/.2/.35/.45/.5
00550 A  EDDSF.K=TABHL(TEDDSF,DDPF.K/DDN,1,3,0.5)
00560 T  TEDDSF=1/.75/.50/.40/.35
00570 A  EECHR.K=ECHR.K*EEC.K
00580 A  ECHR.K=TABHL(TECHR,REVGL/REVIX.K,1,1.5,0.1)
00590 T  TECHR=0/.08/.15/.20/.23/.25
00600 C  REVGL=8
00610 A  EEC.K=TABHL(TEEC,DF.K/NSUF,0,1,0.25)
00620 T     TEEC=1/.45/.20/.07/0
00630 L  DF.K=DF.J+(DT)*(DIN.JK-DUT.JK)
00640 N  DF=NSUF
00650 C  NSUF=15000
00670 R  DIN.KL=AR.JK*RECF
00680 C  RECF=10
00690 R  DUT.KL=S.K*REVGL*RECF
00700 NOTE
00710 NOTE ALLOCATION OF STAFF
00720 NOTE
00730 A  ASP.K=SMOOTH(DAP.K,ACT)
00740 C  ACT=2
00745 A  DAP.K=MIN(IAP.K,ISP.K)
00750 A  ISP.K=Q.K/(SPQR*DDNM)
00760 C  DDNM=0.5
00770 A  ISM.K=U.K*ANEED*NDBIAS
00780 C  NDBIAS=1
00790 A  IFF.K=ISP.K/(ISP.K+ISM.K)
00800 A  IAP.K=IFF.K*S.K
00810 A  ASM.K=S.K-ASP.K
00820 NOTE
00830 NOTE EFFECT OF MARKETING
00840 NOTE
00850 A  ASTND.K=U.K*ANEED
00860 C  ANEED=0.001
00870 A  EMAER.K=TABLE(TEMAER,ASTND.K/ASM.K,0,3,0.25)
00880 T  TEMAER=2/1.55/1.3/1.1/1/.81/.7/.62/.56/.5/.45/.42/.38
00890 C  DDN=0.5
00900 C  PQN=0.035
```

```
00910 NOTE
00920 NOTE  PERFORMANCE AND OPERATIONAL  MEASURES
00930 NOTE
00940 L  SAR.K=SAR.J+(DT)*(AR.JK)
00950 N  SAR=NSAR
00960 C  NSAR=0
00970 L  SER.K=SER.J+(DT)*(ER.JK)
00980 N  SER=NSER
00990 C  NSER=0
01000 A  SRVIX.K=EDDER.K*EMAER.K
01010 A  NER.K=(ER.JK-TR.JK)
01020 A  YPUG.K=(SMOOTH(NER.K,52))*(5200)/U.K
01030 A  QPUG.K=(SMOOTH(NER.K,12))*(1200)/U.K
01040 L  AGOWL.K=AGOWL.J+(DT)*(GWR.JK)
01050 N  AGOWL=NAGOWL
01060 C  NAGOWL=0
01070 R  GWR.KL=SRVIX.K
01080 A  REVIX.K=AVQR.K/AVS.K
01090 A  AVQR.K=SMOOTH(QR.JK,STRA)
01100 A  AVS.K=SMOOTH(S.K,STRA)
01110 C  STRA=26
01120 NOTE
01130 NOTE  INITIAL CONDITIONS AND CONTROL CARDS
01140 NOTE
01150 C  QN=1
01160 C  SN=3
01170 C  UN=50
01180 C  DT=.2
01190 N  TIME=NTIME
01200 C  NTIME=0
01210 C  LENGTH=0
01220 C  PLTPER=8
01230 PLOT  U=U/Q=Q,QR=Q/S=S,ASP=%/ER=E
01240 PLOT  EDDPQ=1,EDDER=2,EMAER=3,EMPER=4(0,2)/
01250 X  DXS=X(-1,1)/EECHR=C,EDDSF=S(0,1)
01260 C  PRTPER=48
01270 PRINT 1)U/2)Q/3)S/4)QR/5)HR/6)ER
01280 PRINT 1)SAR/2)SER/3)EECHR/4)YPUG/5)QPUG/6)AGOWL
01290 RUN
```

The figures in the paper "Growth Dynamics of Information Search Services" were produced by running the model described in the appendix with parameter values according to the following:

Figures 7-a and 7-b	c length=240
Figure 8	c ndbias=2 c length=240
Figure 9	t tedder=1.5/1.3/1/.8/.6/.4/.3 c length=240

The change in the table function defining the effect of delivery delay on entry rate is further illustrated in the following figure.